KWAME NKRUMAH -UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI, GHANA

COLLEGE OF HEALTH SCIENCES

SCHOOL OF PUBLIC HEALTH

DEPARTMENT OF HEALTH PROMOTION AND EDUCATION

MICROBIAL CONTENTS OF HOUSEHOLD WATER IN THE BANTAMA SUB METRO OF THE KUMASI METROPOLITAN ASSEMBLY, GHANA

BY

JACOB AMONOO-NEIZER

MAY, 2019

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(B.Sc BIOLOGICAL SCIENCES)

A THESIS SUBMITED TO THE DEPARTMENT OF HEALTH PROMOTION AND EDUCATION,

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MAY, 2019

DECLARATION

I Jacob Amonoo-Neizer hereby do declare that this work is the results of my own research work and that all the sources that I used have been duly acknowledged by means of references and neither in whole nor in part has this work been presented for the award of a degree in this university or elsewhere

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HEAD OF DEPARTMENT

DEDICATION

This work is dedicated to my Wife Mrs. Abigail Amonoo-Neizer and Sons Israel Jason and Ohene Kwame Amonoo-Neizer, my friend, a brother and spiritual father Ing. Dr.

Eric Ofosu-Antwi (AGYA ADOWA) and the entire Amonoo-Neizer family of Cape Coast, Accra and Kumasi for their prayers and support throughout this course.

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Directorate.

To my colleagues (2014/2015) academic year group of the school of public health, I say thank you for the friendship, support and the sharing of ideas throughout the period that we have known each other ,especially Nicholas Appiagyei and Ebenezer Frimpong, and to all the 300 households within the Bantama Sub metro who agreed and responded to my questionnaire.

To you all, I say thank you and wish you all the best in your endeavors; may others offer you as much care, favour and help as you did to me.

DEFINITION OF TERMS

Agent: Is a disease causing organism often micro-organism that causes disease

Fatal: Very serious condition or situation that often results in death

Incidence rate: Is the occurrence of new case of a disease in a particular area at a particular time

Intervention: they are measures put in place to help bring a problem or health situation to the barest minimum.

Morbidity: Is the occurrence of diseases within a particular area

Mortality: Is the occurrence of death within a particular area

Preventive: Is the measures put in place to help a person to remain healthy

E. coli: *Escherichia coli*

Total coliform: bacteria that are found in the soil, water and human or animal waste

Faecal coliform: group of total coliforms that are considered to be present specifically in the gut and faeces of warm –blooded animals**.**

Colony Forming Units: is the units for enumeration of microbes.

Microbes: a microorganism, especially a disease causing bacterium

Millennium Development Goals: are eight goals with measurable targets and clear deadlines for improving the lives of the world's poorest people

Safe Drinking Water: Is water that "does not represent any significant risk to health over a lifetime of consumption.

Improved Sanitation: is a term used to categorize types or levels of sanitation for monitoring purposes

Contamination: the action or state of making or being made impure by polluting or poisoning

Faecal Contamination: Pollution from microorganisms found in the gastrointestinal tract of animals, including humans.

Pollution: the presence in or introduction into the environment of a substance which has harmful or poisonous effects

Sanitation: generally refers to the provision of facilities and services for the safe disposal of human urine and faeces

Virulence genes: a gene whose presence or activity in an organism's genome is responsible for the pathogenicity of an infective agent

ABREVIATION/ACRONYMS

CDC	-	Center for disease control
CFU	-	Colony Forming Units
CHPS	-	Community Base Health Planning and Service
CWC	-	Child Welfare Clinic
DHD	-	District Health Directorate
DHIMS	-	District Health Information Management System

DHMT	-	District Health Management Team
GHS	-	Ghana Health Service
KMA	-	Kumasi Metropolitan Assembly
KNUST	-	Kwame Nkrumah University of Science and Technology
MOH	-	Ministry of Health
PHC	-	Primary Health Care
SAGE	-	Strategic Advisory Group of Experts
UNICEF	-	United Nation Children‘s Funds
WHO	-	World Health Organization
MDGs	-	Millennium Development Goals
EHEC	-	Enterohaemorrhagic E. coli
ETEC	–	Enterotoxigenic E. coli
EPEC	-	Enteropathogenic E. coli
EAEC	-	Enteroaggresive E. coli
DAEC	-	Diffusely adherent E. coli
NMEC	-	Neonatal meningitis E. coli
UPEC	-	Uropathogenic E. coli
GWCL	-	Ghana Water Company Limited

ABSTRACT

Water is one of the indispensable resources for the continued existence of all living thing including man. An adequate supply of safe drinking water is human right issue. About 2 million death are recorded every year in children under five years due to water borne disease mainly caused pathogenic microorganism .This study was conducted to assess the microbial contents (specifically *Total coliform* and *E.coli*) in the Bantama sub-metro of Kumasi, Ghana between May –July 2016.A qualitative cross-sectional, using a combination of questionnaire, observation and laboratory analysis was employed in this study to collect some primary data in 300 households. Serial dilution and membrane filtration methods were adopted for the microbial water quality analysis and results expressed in cfu/100mls. Three major sources of water to households were identified, thus, pipe borne water from GWCL, water from boreholes and that from hand dug wells.20% of the water were found to contain *Total coliform* of which 14% contains *E.coli,* indicating fecal contamination of these water sources. Statistical analysis were also carried out using SPSS. The study revealed a statistically significant association between educational background and medium for water storage (p = 0.000), there were significant variations in the quality of water between the suburbs (p = 0.011). Contamination water sources by *Total coliform* and *E.coli* were attributed to poor water source protection, poor sanitation, low level of hygiene practices, and lack of monitoring and education. The potential health risks to the consumers of these water sources calls for prompt interventions to mitigate these risks

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Water remains one of the most essential resources for the survival of all living things including man. The availability, as well as the demand and supply of safe drinking water has been a major issue on many international conferences of primary health care. (Gerla *et al*., 2015). Globally, an estimate of three million, four hundred thousand (3.4 million) mortalities are reported annually, stemming from water-related diseases of which diarrhoea alone accounts for Two Million (2 million) death, majority of these victims are children under five years and 99 % of the deaths are recorded in developing countries. (WHO, 2014)

1.2 CURRENT STATE OF KNOWLEDGE

The earth has limited amount of fresh water and its quality has been subjected to constant pressure. The demand for the safeguarding of natural fresh water is paramount for the supply of safe drinking-water, sustenance of food production and recreational water use. The quality of natural water could be endangered by the nearness of harmful biological agents, poisonous synthetic substances, and radiological risks. (UN, 2015)

The drinking-water quality is a major environmental determinant of wellbeing and guaranteeing its security, is the basis for eradicating water borne diseases (WHO, 2016).

Targets for drinking water supply globally under the Millennium Development Goals though exceeded, the situation within the African region were on the contrary. Many an African rural communities and villages are still much more dependent on elective water sources, for example, lakes, streams and rivers for use in their households and for personal hygiene. (Abia *et al*., 2017).

However, research conducted by Bartram *et al*., reveals that global targets for access to enhanced sanitation were not met as compared to the exceeded targets for safe drinking water. A fractional 7% out of the targeted 50% reduction in relation to people who have no access to improved sanitation was realised in Africa according to the article (Bartram *et al*., 2016).

The woefully inadequacies of such sanitation facilities is tantamount to uncontrolled human waste and domestic waste disposal into nearby and surrounding water bodies, resulting in water pollution as stated by Paulse *et al*. (Paulse *et al*,2014)
Consequently, poorly constructed pit lavatories are still being used for human waste transfer and the construction of these pit restrooms tough from, and in closeness to, water sources additionally results to the contamination of these water sources through filtering (Graham *et al*., 2013). Such pollutants are mainly chemicals from pharmaceuticals also, and pathogenic microorganisms. These microorganisms of which may be viruses and or bacteria are parasitic, and have been found to be the major causes for some waterborne infections in people that utilize such unsafe water from such contaminated sources (WHO, 2015)

The WHO, defines safe drinking water as water having acceptable quality in relation to its physical, chemical, radiological and bacteriological components. The presence or absence of Total coliform and *Escherichia coli* (*E.coli*) have been the standard measure in determining the microbial quality of drinking water globally. The presence of E.coli signifies faecal contamination in drinking water. Detection of it, confirms contamination of water source with faecal matter that could contain other pathogenic organisms, i.e. bacteria, viruses, or parasites. (Ahmad *et al*, 2017) Escherichia coli (E.coli) has for quite some time been examined broadly and generally as a pointer living being as a consequences of fecal contamination in water bodies, attributable to the way E.coli has been found to colonize the gut of some warm-blooded mammals.(Bragina *et al*.,2017). Despite the fact that initially thought about as a commensal, the life form has metamorphose to incorporate pathogenic strains, causing both intestinal and extraintestinal infections in human beings.(Abia *et al*., 2017]. Strains that have been found to cause gastrointestinal diseases incorporate the enterohaemorrhagic E. coli (EHEC), enterotoxigenic E. coli (ETEC), enteropathogenic E. coli (EPEC), enteroinvasive E. coli (EIEC) enteroaggresive E. coli (EAEC) and diffusely disciple E. coli (DAEC) (Clarke *et al* ., 2011) and they are on the whole known as diarrhoeagenic E. coli. Those that have been accounted for to cause extraintestinal diseases incorporate neonatal meningitis E. coli (NMEC) and uropathogenic E. coli (UPEC) Their capacity to cause diseases in people lies in various destructiveness attributes which the pathogenic structures have. The harmfulness qualities related with these intestinal and extraintestinal E. coli pathotypes and how they cause sickness, have been explored already (Logue *et al*., 2017, Abia *et al*., 2017).

Countries with no home grown drinking water standards, adopts the WHO standards for drinking water .Data from the WHO in relation to faecal coliform bacteria, puts them into risk categories as follows: 0 cfu/ 100ml (conformity); 1–10 cfu/100 ml (low risk); 10–100 cfu/100 ml (intermediate risk); 100–1000 cfu/ 100ml (high risk); and 41000 cfu/100 ml (very high risk). (Wardrop *et al*., 2017, Bain *et al*., 2014 WHO, 2015)

1.3 PROBLEM STATEMENT

Data from the WHO indicates that more than one billion people world over need access to portable water sources. (WHO, 2013).

Global figures has it that two million four hundred deaths are recorded annually as a result of diarrhoea due to consumption of unsafe water, and poor sanitation, about Ninety Nine Percent (99%) of these deaths are in Sub- Saharan Africa, mainly children below the age of 5 years. (WHO, 2013) Drinking water contaminated with *E. coli* is known to cause stomach and intestinal illness including diarrhoea, dysentery and nausea, which could even lead to death (Bartram *et al*., 2016, Prüss-Ustün *et al*., 2014).

In Ghana estimated deaths per annum is in the region of over Two Thousand, One Hundred (WHO/UNICEF, 2015).

Sub Saharan Africa is bedevilled with water crisis due to scarcity, and mortality rate associated with this condition is sky rocketing. The unavailability of safe drinking water, lead people to consume known unsafe water sources because water is a necessity. (UNICEF/WHO 2015,Emenike *et al*., 2017,)

Ghana is not left out in this global crisis, water scarcity had been reported in many parts of the country, especially during the dry season. (SWN, 2014). The Kumasi metropolitan Assembly has its own share of this global danger, with the Barekese and Owabi Dams operating and producing below capacity (Yeleliere *et al*., 2018) many parts of the metropolis including the Bantama Sub-Metro plunder into water shortages, compelling residents to look for alternative sources of water to satisfy their water needs. These alternative sources of water, of which mostly are unprotected, not treated and likely contaminated by either chemical, bacteriological or radioactive hazards, exposes these residents to many water borne diseases, resulting in the surge of morbidity cases in the region and the country as a whole. (Mwanamoki *et al*., 2014) It was on the basis of this that the study was conducted to assess the microbial contents of household water in the Bantama sub-metro of the Ashanti Region of Ghana.

1.4 JUSTIFICATIONS FOR THE STUDY

Globally, deaths associated with use of contaminated water is estimated to be over two million every year. Accessibility to safe and reliable source of water is a basic human right and essential for sustainable development (WHO, 2015) Therefore guidelines and legislation that have been developed for drinking water are intended to protect the consumer against water-related disease and illness.

The quality of any water could be evaluated only when results of laboratory findings have been interpreted in the light of sanitary survey data (AWWA, 2015.WEF, 2014, APHA, 2014.)Therefore the results of this study will help establish the quality of household water in the Bantama Sub-metro.

Further, the study will serve as a reference documents for the Kumasi Metropolitan Assembly, the Ghana water Company in Kumasi, and individual and organizations alike. Moreover the findings will contribute to existing body of knowledge in water quality in the Kumasi Metropolitan Assembly.

And finally, lives being lost to water related diseases could be saved through the findings of this study.

1.5 RESEARCH QUESTIONS

The research questions to be answered were;

1. What is /are the source(s) of household water within the sub-metro
2. What is /are the most relied upon water source(s) within the selected households?
3. What medium do the people use in fetching and storing water?
4. What is the degree of microbial contamination in the household water?

1.6 OBJECTIVES OF STUDY

1.6.1 GENERAL OBJECTIVES

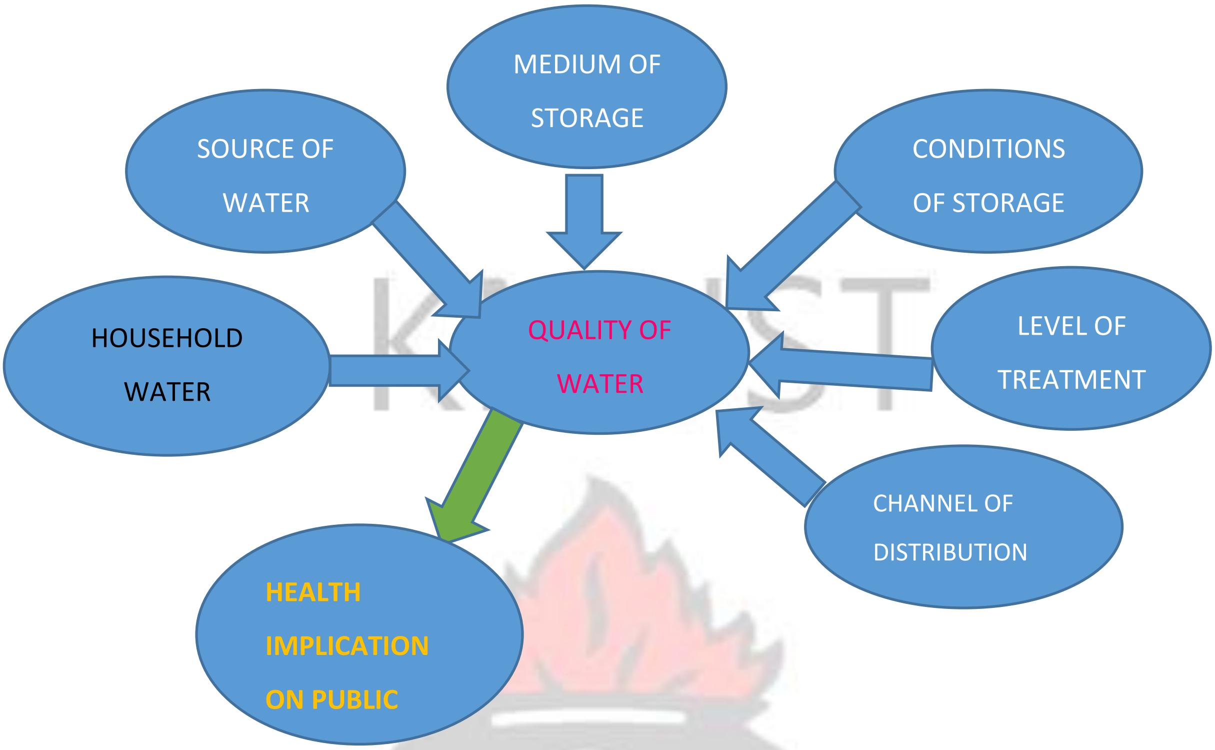
The study sought to assess the microbial contents (specifically *E.coli* and total coliforms) of household water within the Bantama sub-metro of the Kumasi metropolitan assembly of the Ashanti Region of Ghana.

1.6.2 SPECIFIC OBJECTIVES

The specific objectives were; ○ To identify the source(s) of household water within the Sub-metro. ○ To identify the most used /relied upon water source(s) by the people within the community ○ To assess the medium used by the people in fetching and storing water ○ To assess the degree of microbial contaminant (specifically *E.coli and Total coliforms*) in household water within the Community.

1.7 CONCEPTUAL FRAMEWORK

FIGURE 1.1 CONCEPTUAL FRAMEWORK



1.7.1 EXPLANATION TO CONCEPTUAL FRAMEWORK

The quality of water in a household directly impacts the health of the people who uses the water within that household. It is dependent on the source(s) of the water, the medium within which the water is stored and used, conditions under which the water is stored, whether these waters are treated or not before use and the channel through which these waters are distributed.

Such determines the quality of water within a household, which impacts directly on the health of the people and the country at large**.**

Source(s) of the water within the households were identified. (I.e. from Taps, dug wells, streams, rivers, springs, filtered sachet water or bottled water etc.) Sample(s) of these water were taken to the laboratory. Investigations were done on them to isolate *Total coliform and E.coli.*

Identification and estimation of the microorganisms were carried out (estimation in terms of number of colony forming units)

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW

Water is a colourless, odourless, and tasteless and calorie free substance which is very important and a necessity to all life on earth. From the biggest of mammals to smallest of microbe, water is essential. Nothing could be used in place of water. The only naturally existing matter on earth in all the three physical states of matter, i.e., liquid, solid and gas (Quist *et al*., 2018). Chemically, water is a liquid substance in which two hydrogen atoms combine with one oxygen atom to produce a compound of formula H_2O, the only form of water that is absolutely pure. Every human on this planet earth, need water on a daily basis. The amount of water consumed in a day varies from person to person. An average of about two and a half quarts (1.9 Litres) has been the recommendation, but according to climatic conditions, physical activity, biological and physiological condition, this volume could vary considerably(Olivier, 2015).

Literature reviewed confirms that water is an important resource for agriculture, industrial activities and the existence of humankind (Katsiapi *et al*., 2016)

Water is required in adequate quantity and quality to sustain development and other activities by man. When water is polluted or used wastefully, it threatens development projects and therefore there is the need to treat water so as to produce water that is safe for human consumption.

Toxic chemicals discharge, aquifers over pumping, atmospheric transport long-range and water becoming contaminated by substances that invigorates algal development (potentially prompting eutrophication) have recently caused degradation of water quality. (Katsiapi *et al*., 2016) .

It has been proven that water of good quality is essential in promoting socio-economic development. Water frameworks are imperiled on a worldwide dimension by an assortment of toxins and dangerous land-use or water-management practices. A few troubled issues have been available for quite a while now however at a crucial level, while others are now coming up.(Katsiapi *et al*,2016) (Katsiapi, Moustaka-gouni and Sommer, 2016).

Findings from Katsiapi,Moustaka-gouni and Sommer suggests that organic pollution grossly leads to disorder of the oxygen equilibrium and is frequently convoyed by severe pathogenic pollution, as results, high levels of eutrophication due to higher nutritional concentrations originating from industrial effluents, domestic sewage and agricultural run-off affects impounded rivers and Lakes the most.

According to the article, lands for agriculture without strict environmental protection measures to prevent excessive utilization of agrochemicals is impacting negatively on the soil/water ecosystem and the fundamental aquifers. Other key difficulties related to agrarian exercises are salinization, nitrate and pesticide pollution, resulting in higher convergences of suspended solids in water bodies because of disintegration and the siltation of impoundments. Irrigation systems has open-up the land zone suitable for planting yet the subsequent salinization which has happened in some zones has affected negatively the already fertile soils. (Katsiapi, Moustaka-gouni and Sommer, 2016)

Similarly, surface waters are directly polluted by metals that are discharged into water bodies from mines, smelting and industrial manufacturing companies. All things considered, the arrival of airborne metallic contaminants has of late achieved such extents that long-range atmospheric transport causes contamination, not just in the encompassing region of mechanically propelled territories, yet in addition in increasingly remote regions. The writers presumed that humidity in the atmosphere additionally responds to gases delivered when petroleum derivatives are singed, delivering acid rain, and causing acidification of surface waters, particularly to lakes. Pollution of water bodies (both surface and ground water bodies) through leaching from waste dumps, industrial production sites and mine tailings had also been recorded (Katsiapi *et al*., 2016)

2.2 WATER QUALITY

The following review of literature confirms that, the term ―water quality‖ is a widely used term, which has an extremely broad spectrum of meaning. This may involve domestic, commercial and industrial uses or recreational pursuits (Hussain *et al*., 2014). What this means is that each individual has vested interests in water for a particular use.

In his article, Ejiofor, related water quality to its physical, chemical and biological characteristics only. Her study however, was limited in its application as she chose to focus on a few characteristics. (Ejiofor *et al*., 2016). It may have been much more exhaustive to have broaden the scope of the study to have included other characteristics of water. Conti Nibali and Havenith (2014) did precisely that in his broad-scope study which brought on board the chemical, physical, biological and radiological characteristics of water. This is important because the quality of water is based on the constituent concentrations based on scientific data and judgment on the relationship between pollutants concentrations and environmental and human health effects, (Millar *et al*., 2017). It is additionally a proportion of the state of water in respect to the necessities of at least one biotic animal categories and additionally to any human need or reason .

Vystavna *et al*., (2015) also supported the findings of Okolo (2014) , CañedoArgüelles *et al.*, (2016) by showing that the key highlights of water quality in streams, rivers and lakes which are of most concern can be classified into four primary gatherings' specifically physical, chemical, biological and radiological attributes.

According to the Pan African Chemistry Network, the quality of any water is influenced by both natural processes (seasonal trends, geological and hydrological conditions, weather and climatic condition) and by human activities such as agricultural, environmental engineering, industrial and domestic activities. (Khatri and Tyagi, 2015). This is worth nothing and calls for action because an estimated 75% of drinking water in Africa is from groundwater source and is usually used not purified or with just little purification. (Bain *et al*, 2014).The question that needs to be asked, however is how safe are these waters and how reliable are they in relation to the ever growing demand for safe drinking water.

It has been documented that water which has been contaminated by microbiological pollutants is the cause of and spread of disease burden such as diarrhoea, cholera, dysentery and typhoid.

Similarly, chemical contaminants, including those found naturally in the underlying bed rock, is also reported to contribute to the disease burden and developmental problems, and could negatively affect agricultural yields and industrial processes.

However, simplification and understanding of the available information about water quality could significantly reduce if not prevent the burden of disease associated with poor drinking water quality. (UN-WWAP, 2013)

That is why the setting up of the GEMStat database dedicated to water quality by the United Nations Environment Program (UNEP) recently is crucial and a refreshing news. Because from this database information that needs to be will readily be available. (UN/, 2015).

Distinctive nations have diverse water quality benchmarks, and this might be a set down national enactment. An administrative expert is responsible for checking the degree to which the gauges are satisfied (UNEP/GEMS, 2015). This is especially regular for water proposed for drinking and is done as a general wellbeing assurance measure. The check list targets in this case will be about identifying any anomalies in crude water quality with the goal that suitable source intervention or treatment can be put in place. In different occurrences, it might be important to build up another water source so as to meet expanding requests; the goal may then turn into that of observing the quality and amount of sources that may satisfy this need. (UNEP/WHO, 2015). A weakness with this, however, is that many African countries lack the needed resources for such authorities to undertake proper monitoring and evaluation, especially in Sub- Saharan Africa. Leaving a major limitation that needs to be fought and eliminated without delay.

Where water quality enactment is simple or non-existent, the water specialist's order might be to create enactment and directions fitting to the nation's financial improvement designs. For this situation the observing goals will presumably center, in the main case, on obtaining foundation data on water quality. The goals will change as data on water quality is amassed, as issues rise and arrangements are created, and as new requests are made on the water resources. (UNEP/WHO, 2015).

Data from all regions and countries in the world including Africa could be accessed from this data base. Information about the microbiological and hydrological, together with organic matter and contaminants, physicochemical parameters (e.g. pH), major ions and nutrients are contained in this database Though collected data for Africa is not too detailed and in some cases limited to specific regions, it is still worthwhile. *(UN/Global Environment Monitoring System, 2015).*

Strides in enhancement in coverage is promoted in a few sections of the globe, explicitly in the Africa, where it is accounted for that the nature of water is being observed because of a stressing picture emerging, as a result of many an important water bodies, which fills in as drinking water sources, washing and water system for a large number of nearby occupants, demonstrating high and unsatisfactory dimensions of possibly harmful substances which incorporates heavy metals, persistent organic pollutants

(POPs) and biological contaminants. Reports has it that, the origin of these pollutants varies considerably from local industries to domestic waste water. It has become evidently clear that, increased monitoring, could be the sure way in the quest to protect drinking water sources and maintain good water quality and implement preventative policies and practices (UN Water/Africa, 2014).

2.2.1 FEATURES OF WATER QUALITY

2.2.1.1 CHEMICAL CHARACTERISTICS OF WATER

The chemical description of water is H_2O, .i.e. two hydrogen atoms bonded to one oxygen atom. The side where the hydrogen atoms are attached has positively charged water molecules, whereas negatively charged water molecules are found on the side where the oxygen atom is. Water is therefore _sticky' as these opposite electrical charges attract each other. That is why water dissolves more substances than `any other liquid. Water is known to be a universal solvent, many chemical compounds are found in solutions of naturally occurring water sources, hence chemical features of water quality could be inexhaustive, however a selection of the most significant ones were discussed.
(Boyd, 2015).

pH pH is a measure of the acidity or basicity of a solution. Boyd, (2015) in his study findings suggests, It is also the negative logarithm of the acidity divided by the concentration of hydrogen ions and expressed mathematically as pH= -log $[H^{+]}$. It runs from a scale of zero to fourteen. The limitation with this argument, however, is that, it sorely mathematically inclined, and neglects the social sciences aspect of it. This finding would have been more applicable if he had brought on board the social sciences aspect as well. A pH values less than seven is an indication that a particular solution is acidic in nature, equal to seven means a particular solution is neutral and above 7 reflects the basicity of a particular solution.

Water in its pure state is expected to have a neutral pH value, but values between 6.5 to 8.5 have been reported elsewhere as normal pH values for most irrigation waters. Values out this range is said to be not good for irrigation purposes. Variations in water pH values is reported to be due to acid-generated salts and dissolves carbon dioxide which are responsible for low pH values, whereas carbonates, bicarbonates ,hydroxides, phosphates, silicates and borates accounts for high pH values (USGS,2014)

The pH of regular water gives critical data about numerous compounds and natural procedures and indirect correlations to various distinctive debilitations.

Unadulterated water free of dissolved gases will normally end up ionized as; H2O H+ + OH. The exact number of water molecules that will ionize is generally little with the number of hydrogen ions [H+] being equivalent to the sum hydroxide ions [OH-]. At room temperature the concentration of [H+] in unadulterated water will be 1×10^{-7} moles for every liter. A pH of 7 is neutral in light of the fact that the $- \log (1 \text{ X } 10^{-7})$ will be 7 by definition. (Hung *et al*, 2015)

In unpolluted or unadulterated waters, the pH is maintained by the trading of carbon dioxide with the atmosphere. Carbon dioxide is soluble in water and the measure of CO_2 that will break up in the water will be an element of temperature and the concentration of CO_2 in the air. As the vaporous CO_2 becomes aqueous, the CO_2 will be changed into H_2CO_3 which will acidify the water to a pH of around 6. On the off chance that any alkaline earth metals, for example, sodium are available, the carbonates and bicarbonate shaped from the solublization of CO_2 will collaborate with sodium increasing the alkalinity, moving the pH up more than 7 (Environmental Measurement Systems, 2019)

Apart from organic acids and the carbonate chemistry, the acidic pH of crude waters could likewise be controlled by mineral acids delivered by hydrolyses of salts of metals, for example, aluminum and iron. Most metals will turn out to be increasingly dissolvable in water as the pH diminishes. For instance, sulfur in the air from the consuming of coal will results in acid rain. The acid rain, being corrosive will dissolve metals in the shape of copper, lead, zinc and cadmium as the rain keeps running off of artificial structures and into water bodies.

The overabundances of dissolved metals does adversely influence the wellbeing of the aquatic life. (Hung, 2015).

The alkalinity of water bodies is controlled by the concentration of hydroxide and is evidenced by a pH more than 7. This is normally a sign of the measure of carbonates and bicarbonates that moves the equilibrium producing [OH-]. Different supporters of a basic pH are boron, phosphorous, nitrogen containing compounds of potassium. (Boyd, 2015)

Changes in pH could be as a result of industrial contaminants, photosynthesis or the breath of green algae that is feeding on some contaminants. Most ecosystems are very sensitive to changes in pH, therefore monitoring of pH has been fused into the environmental laws of most industrialized nations. pH is normally observed for evaluations of aquatic ecosystems 'wellbeing, recreational waters, irrigation water system sources and releases, domesticated animals drinking water sources, industrial discharges, intakes and storm water runoff (Schweitzer *et al*., 2013).

Therefore, pH estimates the concentration of hydrogen ions (H+) and it is a marker of the level of acidity or alkalinity of water. On the scale from 0 to 14, a pH of 7 means the water is neutral. Where pH is under 7, the water is acidic and if pH is more than 7, the water is alkaline. (Boyd, 2015).

Dissolved oxygen

Dissolved oxygen (DO) is important to all types of aquatic life including the life forms that degrade man-made contaminants. Oxygen is dissolvable in water and the amount of oxygen that is broken down in water will be equal to the oxygen in the air. Oxygen will in general be less soluble as temperature rises. The dissolved oxygen of natural water at sea level will run from 15 mg/l at 0°C to 8mg/l at 25°C. Concentrations of dissolved oxygen of uncontaminated natural water will be in the range of 10mg/l (Schwarzenbach *et al*., 2013).

All in all, the concentrations of dissolved oxygen are dependent on the biological activity in the water body. Photosynthesis of some aquatic plants will elevate the D.O concentrations amidst sunshine hours and the dimensions will fall amid the evening time hours. In natural water bodies, man-made pollutants, or natural material will be devoured by microorganisms, as this microbial movement builds, oxygen will be expended out of the water by these creatures to aid in their digestion process. The water that is close to the dregs will be drained of oxygen thus. In waters defiled with composts, suspended material, or oil squander, microorganisms, for example, microscopic organisms will separate the contaminants. The oxygen will be devoured and the water will end up anaerobic.

Normally, dissolved oxygen levels under 2mg/l is fatal to fish. In situ dissolve oxygen sensors are typically layer anodes and cathodes while research facility techniques are titrations. Other tests for assessing the dissolve oxygen is the biological oxygen demand (BOD) and the chemical oxygen demand (COD). The BOD is the measure of oxygen required to naturally breakdown a contaminant and COD is the measure of oxygen that will be devoured by an oxidizing chemical contaminant. (Schwarzenbach *et al*., 2013). Thus, dissolved oxygen (DO) assumes a key job in the evaluation of water quality. Fish and different types of oceanic life require dissolve oxygen for their sustenance. D.O influences the taste of water and high centralizations of disintegrated oxygen in local supplies are energized by air circulation. Dissolve Oxygen is estimated in

Mg/1(O_2) (Chang *et al*., 2015).

Nitrogen

Nitrogen might be available as organic compounds with most part emanating from household waste. Instances of these compunds are ammonia salts or ammonium salts. Nitrogen could be as nitrites or completely oxidized nitrates. Proportions of nitrogen give a sign of the condition of contamination by organic waste. It is estimated in mg/l (N) (chang *et al*., 2015).

Nitrogen appears in water in an assortment of inorganic and organic form and the concentration of each form is principally interceded by organic movement. Nitrogenfixation carried out by cyanobacteria (blue green algae) and certain microorganisms, changes dissolved molecular N_2 to ammonium (NH_4^+). (Al-janabi and Al-obaidy, 2015)

Oxygen consuming microorganisms convert NH_4+ to nitrate (NO_3-) and nitrite (NO_2-) through nitrification, and anaerobic and facultative microscopic organisms convert NO_3 - and NO_2 - to N_2 gas through denitrification. Primary producers absorb inorganic N as NH_4+ and NO_3-, and organic N is come back to the inorganic nutrient pool through bacterial disintegration and discharge of NH_4+ and amino acids by living beings. Nitrogen in water is normally estimated as aggregate nitrogen, ammonium, nitrate, nitrite, add up to Kjeldahl nitrogen (= organic nitrogen + NH_4+), or as a mix of these parameters to evaluate inorganic or organic nitrogen concentrations. (Li, 2016)

Chlorides

Chlorides are present in hard water bodies polluted via ocean water or in ground water aquifers with high salt water content. The existence of chlorides (mg 1-1Cl) in a stream is sign of sewage contamination from other chloride compounds (Meyer, 2017).

2.2.1.2 PHYSICAL CHARACTERISTICS OF WATER

Water is exceptional, besides it, n other substance exists naturally in each of the three states of matter, (liquid, Solid, (Ice) and Gas (Steam). Incidentally, ice (solid form of water) of is less heavy than the liquid water, (ice), this explains why ice glides on water. In addition, water has a high specific heat index. Which means it can accommodate higher temperature for some time before it starts to get hot. This unique attribute of water controls the rate at which air changes temperature, thus the temperature change between seasons is progressive as opposed to sudden particularly places in close proximity to the seas and other water bodies (USGS, 2013).

Moreover, the high surface tension of water makes it sticky and flexible, and will in general cluster together in drops instead of spread out in a thin film. It is surface tension that aids capillary action, which permits water (and its dissolved materials) to travel through the roots of plants and through the blood vessels in our bodies. (USGS, 2013).

Solids are frequently and normally conveyed along by a streaming waters. These solids might originate from organic or inorganic sources. Precedents incorporate refuse, tree husks, tree trunks, sediment, and stones. While assessing water quality, suspended solids (SS) are estimated in mg /l (Arantes *et al* 2016).

Color, Taste and Odor

Shading, taste and scent are properties that are subjectively decided. They are caused by impurities that are dissolved either from natural sources or from the release of toxic substances like excreta, oil, bathwater into the water course by man (Kamau,2015).

Turbidity

Turbidity alludes to the cloudines of water because of fine suspended colloidal particles of mud or residue, squander effluents or microorganisms and is estimated in nephelometric turbidity units (NTU)(Kamau, 2015)

Turbidity or Total Suspended Solids (TSS) is the material in water that influences the transparency or light dispersing of the water. The estimation unit used to portray turbidity is Nephelometric Turbidity Unit (NTU). The range for natural water is 1 to 2000 NTU. There are various manual field strategies for estimating TSS, for example, Secchi discs where a metal circle is brought down into the water with a calibration line. The profundity at which the disc vanishes is directly correlated to TSS. In situ electronic turbidity sensors measure the backscatter of infrared light to decide the NTU of the water

The most common reasons for turbidity in lakes and rivers are plankton and soil erosion. Reasonably low dimensions of turbidity may demonstrate a solid, well-working ecosystem, with moderate measures of tiny fish present to fuel the food chain. Be that as it may, larger amounts of turbidity represent a few issues for stream frameworks. Turbidity shut out the light required by submerged oceanic vegetation. It additionally can raise surface water temperatures higher than average in light of the fact that suspended particles close to the surface encourage the absorption of heat from sunlight. Turbid waters may likewise be low in dissolved oxygen. High turbidity may result from silt bearing overflow, or nutritional supplements inputs that aid plankton to blossoms. Turbidity can cause the discolouring of sinks and installations and additionally the staining of fabrics. (Hudson and Vandergucht, 2015)

Electrical conductivity

Electrical conductivity (EC), additionally called saltiness, emerges from weathering of rocks and soils. Saltwater interruption into water supplies situated close the beach front regions likewise may add to electrical conductivity. (Environmental Measurement Systems, 2019). As indicated by (Vanuytrecht *et al*., 2014) electrical conductivity is broadly used to show the aggregate ionized constituents of water. It is directly proportional to the entirety of the cations (or anions), as decided chemically and is firmly related, as a rule, with the aggregate salt concentration. Electrical conductivity is a fast and reasonably exact assurance, and qualities are constantly communicated at a standard temperature of 25°C to help in comparison, readings taken under fluctuating climatic conditions. It ought to be noticed that the electrical conductivity of solutions rises by roughly 2 % per °C increment in temperature.

Sappa *et al*., (2019) expressed that the essential impact of high electrical conductivity of water (ECw) on crop productivity is the powerlessness of the plants to rival ions in the dirt answer for water (physiological dry spell). The higher the ECw, the less water is accessible to plants, despite the fact that the ground may seem wet. Since plants can only transpire ―unadulterated" water, usable plant water in the soil diminishes drastically as EC increases. The symbol ECw, is utilized to represent the electrical conductivity of irrigation water. The unit of electrical conductivity is deciSiemen per meter (dS/m) or millimhos per centimeter (mmhos/cm) and might be changed over into aggregate dissolved salt conccentration by multiplying mmhos/cm by 640 or 700 (Kamau, 2015). For irrigation purposes, FAO permissible limit for the irrigation water should not be more than 3.0 dS/m (Sappa *et al*., 2019).

Temperature

Temperature is estimated in degree Celsius (°C) and is a decent measure for evaluating the impacts of temperature changes on living organisms. (Hudson and Vandergucht, 2015)

Water Temperature is a controlling element for amphibian life: it controls the rate of metabolic activities, regenerative activities and along these lines, life cycles. In the event that stream temperatures rises, decline or become unstable too generally, metabolic activities may accelerate, back off, glitch, or stop entirely. (Manahan, 2017).

There are numerous elements that can impact the stream temperature. Water temperatures can change occasionally, every day, and even hourly, particularly in smaller streams. Spring releases and overhanging shelter of stream vegetation gives shade and helps cushion the impacts of temperature changes. Water temperature is additionally affected by the amount and speed of stream and the temperature of effluents dumped into the water. At the point when individuals dump warmed effluents into conduits, the effluents raise the temperature of the water.

The sun has significantly less impact in warming the waters of streams with more prominent and swifter streaming than of streams with smaller, slower flows. Temperature influences the concentration of dissolve oxygen in a water body. Oxygen is readily dissolved in cold water (Zhang *et al*., 2015).

In his article, Orjiakor *et al*., (2017), cited Adefemi and Awokunmi‘s research work which reported the temperature of Ona river in Itaogbolu area of Ondo State- Nigeria a farming village, to be higher than those obtained from wells. Temperature of the samples was in the range 25.10- 27.10˚C. Studies conducted in a petrochemical area in Ubeji community in Nigeria have shown a stream temperature mean of 27.5 to be higher .However, the seasons these samples were taken was not indicated even though it has been established that seasons may affect the water temperatures. (Orjiakor *et al*., 2017)

2.2.1.3 BIOLOGICAL CHARACTERISTICS OF WATER

The most widely used monitoring metrics as biological indicators for water is the Ephemeroptera, Plecoptera and Trichoptera (EPT) indexes. These are members of the insect order (common names are mayfly,stonefly and caddisfly). These indexes naturally vary from region to region but the general principle remains that the greater the number of texa from these orders of insects, the better the water quality in that environment (Edward Dewalt and South, 2015)

Radiological characteristics of water

This final characteristic is unique because health threats posed by this group are not always as a result of ingestion, majority of contamination from these radionuclides in drinking water are from natural sources and not from human contamination. The common radionuclides that are associated with this group are radon, radium-226, radium-228, and uranium, cesium, plutonium (EPA, 2016)

2.3 ACCESS TO WATER

Access to clean drinking water and essential sanitation, including toilets, waste water treatment and reusing, influences a nation's developmental advancement as far as human wellbeing, education and gender equality. The provision of sustainable drinking water and sanitation are lacking in most parts of Africa and where accessible, water supply and sanitation services are differentiated by urban, rural or casual settlements (Emenike *et al*., 2017).

Provision of consumable water changes among urban, rural and peri-urban tenants. The middle and high class society urban tenants get water from major streams, dams and profound well sources. A large portion of Africa's rural and peri-urban water-destitute rely upon smaller tributaries and catchments and seasonal rivers. They additionally approach shallow boreholes and rain water catchment. The majority of the ground water resources have not been evaluated, nor assessed to survey the withdrawal and revive rates, and indeed, when appropriately used, Africa's aquifers may give enough water to the developing populace as long as the water withdrawal and energize rates are settled. (Grönwall, 2016).

As anyone might expect, African towns and urban areas have better water supplies and sanitation administrations than rural areas, yet 66% of the African populace live in the countryside. An estimated 82% of urban occupants in Sub-Saharan Africa have access safe water and 55% to sanitation facilities. Improved water supply and sanitation services in the urban regions are amassed in the upper and middle class zones. The urban poor have minimal access to these facilities and pay the most cost for their water. Further separation is made between urban centres with declining water distribution systems, because of lack of it, over aged and over-burden systems and the circumstance of periurban dwellers.

The absence of sufficient water supply at home or in its immediate region is a specific issue for ladies and young ladies, who are regularly in charge of bringing water, frequently from sources which are far from home. In provincial districts of Africa, they go through, by and large, three hours daily occupied with the accumulation of water for a group of six. This limits their chances for formal education, to state nothing of the physical burden to which they are subsequently exposed.

A central issue in the water supply and sanitation segment in developing nations is measuring the readiness of people to deal with their water sources through the commitment of time and resources, (Hutchings *et al*., 2015). The rational is that contributing additional time and resources to the protection and upkeep of rural water supply sources is a positive activity that may conceivably enhance the supportability of water supply infrastructures. Gleitsmann *et al*., (2015), emphatically contend that community engagement, even at the lower levels of participation, is a "perquisite for sustainability". The participating communities depending on their eagerness to contribute, increase inclusion, efficiency, empowerment, and the general maintainability of water supply ventures (Marks *et al*., 2014). Comparative discoveries were exhibited by Gleitmann *et al*., (2015) and Kumau (2015), especially referencing that an demand responsive approach (DRA) essentially builds the supportability of water supply ventures.

Community members' commitments may appear as cash, work, material, hardware, or participation in project- related decision making l and gatherings (Haapala *et al.*, 2016). In addition, Amos and Rahman (2016) portrayed types of commitment, for example, the outflow of demand for water, choice of the innovation and zone, money related commitments, provision of work and materials, and choice of the executive frameworks. Bakker, (2013) clarified that about 98% of World Bank-sponsored Rural Water and Sanitation ventures have incorporated some money commitments from beneficiary communities between 1977 and 2003.

Moreover, the authors demonstrated that 86% of the projects included labor demands and 78% upheld material commitments, for example, wood, while 100% of the World Bank ventures expected operation and maintenance expenses to be completely secured by the beneficiary communities. Willingness to-pay (WTP) by physical money, materials, labor, and upkeep can be taken as a helpful pointer of the interest for enhanced and continued water services. (Haapala *et al.*, 2016)

As indicated by Moreno *et al*. (2015), in the event that individuals will pay for an specific service, it is conceivable to reason that they esteem the service. In like manner, if family units will contribute money and work which is helpful for the management of water resources, unmistakably the services that they get from a source is valuable to them and that they have a positive mentality towards advancing its sustainability.

Marques, da Cruz and Pires (2015) indicated that WTP for enhanced water supplies increases alongside increments in riches, family size, and the educational level of user households. An examination made by Cruz and Pires additionally demonstrated that WTP for water is profoundly associated with source dependability, reliability of WUCs, convinience of area, and water quality; then again, there was no noteworthy connection between the sex, age or financial status of respondents.

Eventually, enhanced planning strategies which completely consider the value and request put on various dimensions service by the community are a need for the sustainability of water systems (Thornton *et al*., 2017) .

2.4 SOURCE(S) OF WATER TO THE HOUSEHOLDS

Water is one of the fundamentals that sustains all types of plant and animal life (Thompson,2015) and it is normally gotten from two primary common sources; These are (1) Surface water for example, fresh water lakes, rivers, streams, and so forth and (2) Ground water, for example, borehole water and well water (Mosley, 2015). Water has unique chemical properties because of its polarity and hydrogen bonds, which implies it can dissolve, absorb, or suspend a wide range of compounds (Morawietz *et al*., 2016), in so doing, in nature, water is not pure as it gains contaminants from its environment and those emerging from people and creatures animals and in addition other biological activities.

In general, surface water and underground water are the two main sources of water available to man (Nilsson and Pettersson, 2015).

2.4.1 SURFACE WATER

Surface water includes water on the surface of earth, i.e. streams, rivers bodies, ponds, oceans, and lakes. Rain water and melting of snow contributes to the water in rivers and lakes. Surface water comes about due to direct runoff resulting from precipitation of rain, snow or both.

Direct runoff is that water that does not enter the ground through intrusion or evaporate to the atmosphere but rather flows on the surface of the ground. It can also be termed as that water that drains from saturated or impermeable surfaces, into their natural or artificial storage sites. (Conrad *et al.*, 2018)

The amount surface water available at any time period is dependent largely on rainfall. The availability and the supply of surface water varies considerably between wet and dry seasons of the year (Gain, 2014).

2.4.1.1 TAP WATER

Water flowing specifically from a faucet or tap that has been filtered, distilled, refined, or treated is referred to as tap water.

Ghana Water Company is the major provider of water utility services in Ghana, with most of rivers and lakes serving as their source of water. Danger looms as many of such water bodies are constantly being polluted by illegal mining activities (galamsey), farming close to the water bodies, untreated sewerage and other human activities (Mensah *et al*., .2015).

Pipe Borne Water supply to households in the Kumasi metropolis is mainly by the Ghana Water Company. It supplies about 80% of daily water needs via the Barekese (on the Offin River) and Owabi treatment plants (Owabi River) in the Ashanti Region of Ghana (Akoto and Abankwa, 2014) These are two major surface water bodies that provide water to the people of Kumasi and its environs. The Barekese dam is supposed to supply about 30 million gallons of portable water per day whilst the Owabi dam is to contribute about 12 million gallons of water per day. But currently these two water treatment plants are producing way below capacity due to a lot of factors, In view of the shortfall in the supply, many people resort to untreated water sources for their daily water needs, as a result water related morbidity and mortality is on the ascendancy hence a gab in the daily water demand and supply in the

Metropolis and its environs (Addo *et al*., 2016).

2.4.1.2 RAIN WATER HARVESTING

Rain water harvesting is another source of water to the households. During the major raining season (April-July) Rain water is harvested into various forms of water storage medium ranging from buckets, gallons, Barrel and tanks for use in the various households (Kostyla *et al.*, 2015).

2.4.2 UNDERGROUND WATER

Subsurface water contained in the interconnected pores below the water-table of an aquifer is termed Underground water. Underground water comes to fruition because of water moving through the impermeable surface obstruction, through the unsaturated zone and gathers in the spaces made by interconnecting pores. The impermeable layer can be of bedrock or that of one rock. When the water streams down to the saturated zone, it streams from the high water-table point to a lower point, this stream of water happens because of percolation. Water permeating inside the saturated zone may, inevitably, move to streams, rivers and other surface water bodies .Access to underground water is mainly through Boreholes, Dug wells or springs (Okolo, 2014).

2.4.2.1 BOREHOLE

A borehole is a form of well that is driven by an electric pump that taps into the underground stores of water held in permeable rock as aquifers .Vertical pipes which serves as casing or screen are installed to prevent contaminants of microbes and other

pollutants entering the borehole, and also ensures that sand and other sediments are not drawn into the installed pumps (Fisher *et al*, 2015). To compensate for shortages in supply of water to the households from the public supply systems, many individuals within the Kumasi metropolis have resorted to boreholes as their source of water in the household. Construction of a borehole is relatively expensive and mostly middle to high level income households are the ones who acquire them. (Maliva,
2016).

2.4.2.2 DUG WELLS

Dug wells are constructed by excavating the ground to a level lower than water table.
This continues till the bailing rate of the digger is exceeded by the incoming water. Some dug wells are lined with either culverts, stones, bricks or mortar to prevent collapse, or caving inn. Wood caps, concrete caps or stones usually constitute the covering. Additionally, dug wells are usually not very deep, (averaging between 10 30 feet deep depending on the nature of the ground and the location of the water table) owing to the difficulty in digging beneath the water table (Conrad *et al.*, 2018) Consequently, there remains a higher risk of contamination with dug wells (Boateng *et al.*, 2015).Dug well also serve many households (low and lower middle income households) within the metropolis as their source of water.

2.4.2.3 SPRINGS

Surface water will filter down the ground through soil layers and rocks till it reaches a point that it cannot pass through (an impervious layer), or it gets to a level in the ground where it is saturated with water (the water table). The water table is shaped similar to the shape of the land surface above it. (Boyd, 2014).

Groundwater flows down slopes in the water table till it intersects the land surface or is forced up to the surface by an impervious layer. When aquifers are filled to a point where the water overflows onto the surface of the land, it results in a spring formation. Classification of springs is based on the geologic formation from which water is obtained by the spring, thus (lava-rock spring or limestone spring); or by the volumes of water discharged by the spring (small or large); or based on the ranges of temperature of the water from the spring (cold, warm or hot) or according to the causative forces of the spring - gravity or artesian flow. (Sappa *et al*., 2015) In some instances, passage of streams and rivers are underground, to reappear downstream, this scenario occurs mostly in limestone areas and may appear as springs, however the degree of filtration may not be same as naturally occurring springs, therefore the safety of such water sources could not be guaranteed. Basically, two main types of springs exists: gravity springs and artesian springs.

The development of groundwater on the land surface because of the impacts of an impenetrable layer upsetting the descending drainage is named as a Gravity spring, or the water table is at indistinguishable range from the land. This sort of spring typically happens on slanting ground and its streams changes with variations in the height of the water table. (NGWA, 2015). The flow tends to vary with the time of year such as; Seasonal gravity spring; Permanent gravity spring, Dry or Wet season water table.

On the other hand, when groundwater surfaces on the land as a result of confinement between two impervious layers of rock, the end product becomes Artesian springs.(Powel *et al*., 2013,) Springs are rare sources of water to households within the Kumasi metropolis.

2.5 WATER USE AND RELIABILITY OF WATER SOURCES

2.5.1 WATER USE

Worldwide water is mainly used for Agricultural, Industrial and Domestic purposes (WWAP, 2015). However, quantities of water used for agriculture and industries vary extensively from one country to another depending on the number and scale of agricultural and industrial activities undertaken by a country. Contrary to the above, domestic water usage has a range, according to the UN, domestic water needs of every human being is estimated to be about 50 litres of water per person per day on the average (UN,2015). This accounts for drinking, meals preparation and other personal hygiene.

However, many an African must do with less than 50% of the UN's estimation. An average of less than 20 litres of water per person per day is the quantity of water utilized in many African countries, due to scarcity and inadequacies of this life dependent resource (IWFA, 2014).

The Water Resources, Works and Housing in Ghana estimates the average individual domestic water consumption to be five gallons a day, agreeing to the figures put out by the Institute Water for Africa (WHO/UNICEF, 2014).

2.5.2 RELIABILITY OF WATER SOURCES

The reliability of a water source is dependent upon the quantity, quality and accessibility of the water source available to the consumer. The main aim of any major water distribution network is to reach the consumer with water in right demanded quantity and pressure, and on time with acceptable quality in terms of appearance, flavor, odour, and sanitary security (Gain *et al.*, 2016).

There are uncertainties associated with water distribution systems, this could arise due to natural occurrences (seasons and changes in climatic conditions or force majeure), design or operational failures. In view of this, the reliability of water is assessed with probabilistic measures (Zyoud *et al*., 2016; Ashbolt, 2015; Gain *et al*., 2016).

The African continent has major water issues, from water stress zones to crisis zones. The unpredictable climatic conditions make many water sources fed by rain very unreliable. Travelling long distances to fetch water because of scarcity resulting from drought, compel many an African do with whatever water available, irrespective of the quality or quantity (WHO/UNICEF, 2015).

Supply of good drinking water in Ghana has a number of difficulties which is not limited to very limited access, intermittent supply, high water losses and low water pressure. This makes public water supply not entirely reliable (Akoto and Abankwa, 2014).

2.6 MEDIUM USED FOR STORING AND FETCHING WATER

2.6.1 MEDIUM FOR STORING WATER

In the world over, water is stored for a number of reason and for applications such as drinking, food preparation, bathing and washing, irrigation, firefighting, and manufacturing of goods. Irrespective of what the intended use is, water is always stored in tanks. A water tank is a container for storing water for future use. These water storage tanks vary in sizes, from very large tanks for commercial water storage, medium sizes for industrial use and relatively small sizes for domestic purposes.

These medium for water storage are made of various materials such as wood, clay (earthen pots), stone, concrete, steel, plastics (polyethylene, polypropylene) and fiberglass (Bohmelt *et al*., 2014) and depending on the intended use, these tanks are situated either underground, over ground or overhead.

The African continent faces major challenges as far as access to clean water is concerned. In the year 2006, The World Health Organization reported that only 16% of the people in sub-Saharan Africa had access to drinking water through a household connection (an indoor tap or a tap within the yard). (WHO / UNICEF , 2014). This presupposes that over 80% of Africans store water in one medium or the other for future use. These medium in times past were tanks carved from wood, earthen pots, or stone/concrete. Recently, steel tanks, plastics and fiberglass have emerged with the advancement of technology. Many a rural African still make use of wooden and earthen pots for water storage.

And in Ghana, the situation is no different, water is stored in almost every household for domestic purposes (Acheampong *et al*., 2016)

2.6.2 MEDIUM FOR FETCHING WATER

Fetching of water for domestic use is synonymous in Africa. The developed western countries has little to do with fetching water for domestic use, reason being that almost every home has water piped in to it and flows almost every day. In Africa, the burden of fetching water for domestic use falls disproportionately on women and children, especially girls. (UNICEF, 2016).

Some women and girls travel long distances before they could get water for their household to use, with far reaching consequences.

Different media are used in fetching water in Africa. Ranging from metal barrels /drums most of which are usually gotten after lubricants for vehicles and trucks have been used ,plastic barrels /drums (these two are normally used by men in fetching water, and are usually carted or transported on either a donkey, moto-king or manually pushed trucks) but usually medium used mostly by women and girls on daily basis for fetching water include head pans (both metal and plastic), buckets (both metal and plastic) and more predominantly of late plastic gallons (plastic jerry can) most of which have been used originally for vegetable oil packaging (WSUP,2015). It is a sight that greets everyone, to find women, girls and sometimes even children carrying water on their heads in various medium in rural, peri-urban as well as urban communities in Ghana. Water is used every day, and fetching of water for domestic use in Ghana and other African countries is a daily routine (UNICEF, 2016).

2.7 WATER CONTAMINATION AND ITS EFFECTS

2.7.1 WATER CONTAMINATION

Water is said to be contaminated when hazardous materials of any kind pollutes water making it not fit for its intended use (Nnadozie, 2015). These hazardous materials could come from direct (point) and indirect (non-point) sources. Direct sources include effluent outfalls from factories, refineries, waste treatment plants etc. Rain and associated run-off water accounts for the indirect sources which contaminate water bodies through washing and sweeping of residue from fertilizers and pesticides used on agricultural lands, improper disposal of industrial and domestic waste and atmospheric contaminants resulting from emissions from automobiles and factories (Okolo, 2014).

2.7.2 EFFECTS OF WATER CONTAMINATION

Contamination of water bodies arising from fertilizers and sewage is said to contain certain nutrients which are of phosphate and nitrates compounds. Over stimulation of growth of some aquatic plants and algae has been recorded as a results of excesses in levels of such compounds. Such incidence of over growth consequently clogs our waterways, make use of dissolved oxygen in these water bodies as and when they decompose and turn to block light to deeper waters. (Bain *et al*., 2014; Boulding and Ginn, 2014).

This impacts negatively on aquatic organisms, as the respiratory ability of fishes and other invertebrates that reside in these waters are seriously compromised, resulting in

the death of large numbers of aquatic organisms leading to disruptions in the food chain (Bain *et al*., 2014). Pathogenic organisms in water such bacteria, viruses and protozoans cause many illness that range from typhoid, cholera, Amoebiasis and dysentery in humans, some of which results in mortalities. Contamination from chemicals used for pesticides, Lead, Arsenic and high levels of fluoride causes nervous system breakdown, cirrhosis of the liver, skin cancers to name but a few
(EPA,2016).

2.7.3 TYPES OF WATER CONTAMINANTS

As per the Safe Drinking Water Act, a contaminant is any physical, chemical, biological or radiological substance or matter in water.

It presupposes that anything other than water molecule is a contaminant. (Pruss-Ustun *et al*., 2014). . Drinking water is anticipated to contain minute quantities of some contaminant. The sighting of contaminants does not mean that the water is dangerous to health, but the levels of these contaminants is what matters. Some drinking water contaminants might be unsafe at some concentrations while others may not.

The following are the types of drinking water contaminant;

Physical contaminants: principally affect the physical appearance or other physical properties of water. Instances of physical contaminants are residue or natural material suspended in the water of lakes, waterways and streams from soil disintegration. (EPA, 2016).

Chemical contaminants: are elements or compounds. These contaminants might come about by nature or man-made. Instances of these contaminants incorporate nitrogen, dye, salts, pesticides, metals, poisons delivered by microbes, and human or animal medications. (EPA, 2016).

Biological contaminants: are creatures in water bodies. They are additionally alluded to as microorganisms or microbiological contaminants. Examples of biological or microbial contaminants include bacteria, viruses, protozoan, and parasites. (EPA, 2016).

Radiological contaminants: are chemical components with an unequal number of protons and neutrons bringing about fluctuating atoms that can emanate ionizing radiation. Instances of radiological contaminants incorporate cesium, plutonium, radon, radium, and uranium. (EPA, 2016).

2.8 THE DEGREE OF MICROBIAL CONTAMINANT (SPECIFICALLY E.COLI AND TOTAL COLIFORMS)

Water devoid of microbial contaminants is medicinal for good health. Maintenance of the microbiological quality of water has been used as an important means of preventing water borne diseases throughout the 20th century and more recent work suggest that gastro-intestinal disease is more strongly associated with the presence of enterococci than of *E. Coli* (Fewtrell and Kay, 2015). Most type of coliform bacteria are not infectious. Some are present in faecal matters which are often the source of most water borne infectious microorganisms. In areas with poor standards of hygiene and sanitation, contamination of water with infected faecal material is common (Fewtrell and Kay, 2015). When more than one sample is taken each year, the degree of faecal contamination varies widely between successive samples. A couple of reasons could be assigned to these variations. Some are obvious, of which seasonal variations such as rainfall has related influences (Kostyla *et al.*, 2015;; Kumpel and Nelson, 2016). Drinking water without any coliform in 100ml of water is considered adequately safe. In developing countries, especially in Africa, it is on record that one of the main routes of microbial pathogenic infections is through drinking water, though poor sanitation and food are also said to be major sources of enteric pathogen exposure. (Ashbolt, 2015) Pathogenic organisms (Disease-causing organisms) transmitted through drinking water are mostly from faecal contamination, and therefore referred to as enteric pathogens (Fewtrell and Kay, 2015; Kumpel and Nelson, 2016). From the 1850's when pioneers of epidemiology like John Snow established the fact that cholera was waterborne, (Akoto and Abankwa, 2014), a deeper knowledge of the route of transmission of various disease causing organisms (e.g diarrhoea) and other related diseases through drinking water has been amassed. (Gomi *et al*.,2014). Moreover, the effectiveness of drinking water treatment (traditionally by filtration and chlorination) to get rid of the pathogenic bacteria that causes cholera (Vibrio cholerae) and typhoid fevers (Salmonella typhi and

S. paratyphi), is well indexed by the common faecal indicator bacterium *Escherichia coli* (*E. coli*), which is excreted in the faeces of all warm-blooded animals and some reptiles (Bain *et al*., 2014; Ceuppens *et al*., 2014).

Total Coliform, a group of bacteria said to be ubiquitous in nature, some of which are not harmful to human health. However, these microorganisms are not naturally present in groundwater but when they do it is an indication that more harmful organisms may be present. (Martin *et al*., 2016) Fecal Coliform and *E. coli* are subjects of the Total Coliform group which originate from fecal matter of most warm blooded animals. Presence of *E. coli* in water, is an indication that the water has been pre -exposed to feces and an immediate risk to human health exist, therefore total coliforms (TC) and *Escherichia coli (E. coli)* are indicator organisms (EPA, 2015). *E. coli* is the main individual from the aggregate coliform gathering of microscopic organisms that is discovered just in the digestion tracts of warm blooded creatures, including people. The presence of *E. coli* in water shows recent fecal pollution and may demonstrate the possibility of illness causing pathogens, for example, bacteria, viruses, and parasites. Albeit most strains of *E. coli* are safe, certain strains, for example, E. coli O157:H7, may cause ailment such as hemorrhagic diarrhea and hemolytic uremic syndrome (HUS) which causes kidney failure, especially in young children and elderly persons (Saxena *et al*, 2015).

The microbial nature of water is dictated by the contamination of microscopic organisms, characteristic of fecal (sewage) pollution, to be specific, total coliforms and fecal coliforms, for example, *Escherichia coli*. Coliforms are normally found in soil and in the gut of human beings and other animals. In this regard, their presence in water may mean that water is contaminated. *E. coli* and certain types of *Enterobacter aerogenesa* are present just in the gut of humans and other creatures. Their detection in water demonstrates unequivocal fecal contamination. The detection of coliforms in well water might be because of surface water penetration or drainage from a septic system (Cobbinah, *et al*., 2016). Total coliforms are a gathering of microorganisms regularly found in nature, for instance in soil or vegetation, and also the digestive organs of warm blooded creatures, including people. Total coliform microscopic organisms are not prone to cause disease, but rather their essence shows that your water supply might be polluted by pathogenic microorganisms (Nnadozie, 2015; Cobbinah,*et al*., 2016) The outbreak of diarrhea on the African continent as results of faecal contamination of water bodies is very common and often. Major cities in Africa including Ghana record cholera and dysentery outbreak, almost every year, claiming lives, most of whom are children (Akoto and Abankwa, 2014).

The World Health Organization group faecal coliform bacteria into the following risk categories: 0 cfu/ 100ml (conformity); 1–10 cfu/100 ml (low risk); 10–100 cfu/100 ml (intermediate risk); 100–1000 cfu/ 100ml (high risk); and 41000 cfu/100 ml (very high risk) (Gruber *et al*, 2014).

Total coliforms and *E. coli* are utilized as pointers to quantify the level of contamination and sterile nature of well water, since testing for every single documented pathogen is burdensome and costly process. The primary source of pathogens in drinking water is through recent pollution from human or animal waste, from inappropriately treated septic and sewage releases; leaching of animal manure; Storm water overflow and domestic animals or wild life. (Igbinovia *et al*., 2016).

Amidst and after precipitation, microbes and other harmful microorganisms from any of these sources might be washed into streams, lakes, or groundwater. Poor well development or poor upkeep can raise the risk levels of groundwater pollution.

In water, coliform microbes have no taste, smell, or colour. The only way to detect their presence is by conducting the appropriate investigations in a laboratory. The Canadian drinking water quality rule for aggregate coliforms is none distinguishable per 100 mL. The Canadian drinking water quality standards for total coliform and *Escherichia coli* is none detectable(zero) per 100 mL. This implies that, for one to meet the standards, for each 100 mL of drinking water tested, no aggregate coliforms or *E. coli* ought to be identified [0 colony forming units per 100 milliliters (0 CFU/100 mL)]. (Nnadozie, 2015; Katsiapi *et al*, 2016).

The adverse impacts of pathogenic microorganisms infection in drinking water is many and differs. The most well-known side effects of waterborne ailment includes nausea, vomiting, and diarrhea. Newborn children, the elderly, and those with compromised immune system may have greater adverse effect. In extraordinary cases, a few pathogens may taint the lungs, skin, eyes, nervous system, kidneys or liver and the impacts might be increasingly serious, endless, or even deadly. One ought not to accept that one's water is safe with the simple reason that it has not made him/her ill before. In the event that microorganisms are present in one's water, there is that risk it could make him/her sick.

(Parveen and Zaidi, 2017).

Microscopic organisms cannot be expelled from water with pitcher-type carbon filters. Microscopic organisms can be evacuated by keeping water at a rolling boil not less than one minute. Viable treatment strategies for microbial pollution include: Permanent point of-entry disinfection units, which can utilize chlorine, ozone, Ultraviolet light (UV light) and distillation (Devi- K *et al*., 2015).

2.9 SUMMARY OF LITERATURE

The total amount of water the earth contains is essentially constant, because the earth is a closed system. (Wade *et al*., 2017). And as the world population increases, the need for water increases as well. The quality of drinking water is under constant threat as many water bodies are being polluted on a daily basis. Water related morbidity and mortality are on the ascendancy, and there is a looming danger for humanity as far as access to portable water is concerned. (Mukhopadhyay *et al*., 2017). The lack of access to this life dependent resource in Africa, has compelled many Africans to sources of water that predisposes them to faecal contamination, rendering the water unsafe for drinking. Many lives have been lost and a lot more is on the verge. Water supply systems are becoming increasingly unreliable, exploration of alternative water sources has exposes mankind to lots of contamination, some with grave consequences. The levels of contamination by faecal matter is a major problem in most of our households in Africa and for that matter Ghana, and urgent attention is needed to curb this treat to save lives .threat

(WHO,2015).

CHAPTER THREE

METHODOLOGY

3.0 INTRODUCTION

This chapter outlines how the study was conducted and the procedures used in the collection, collation and analysis of the data as well as various statistical tools used in the analysis.

3.1 STUDY METHODS AND DESIGN

The study employed a combination of questionnaire, Observation and laboratory analysis, aimed at assessing the microbial contents of household water in the Bantama sub-metro of the Kumasi metropolitan Assembly of Ghana, in the months of May and July, 2016.

Primary data was collected using a questionnaire aimed at determining the sources of the water within the households, their uses, the most reliable source and the medium used in fetching and storing the water in the household. However, direct spot observation of sanitation indicators were taken by the researcher, such as location of septic tank in the house , refuse container/ bin covered or not covered, water storage medium covered or not then water samples of the water in the households were taken, transported on ice and cultured on suitable culture medium for identification and counting of microorganisms.

3.2 PROFILE OF STUDY AREA

The study was conducted in the Bantama Sub-metro, in the Kumasi Metropolis. It is west of Kumasi, and the second largest city in Ghana which is 270 km north of the national capital, Accra. The Sub-metro is bounded by Atwima and Bosomtwe-Atwima Kwanwoma to the North West and South West respectively and to the East by Asokwa,

Manhyia and Subin. It is the second largest Sub-metro in the Kumasi Metropolitan Assembly, and has an estimated population of 478,419 which constitutes 24.2% of the metro Population. The Bantama sub-metro has fifteen private hospitals, one public hospital, one psychiatric hospital, sixteen private clinics, Two Christian Health Association of Ghana (CHAG) facilities, one community clinic, eight maternity homes, seventy pharmacy shops and One Hundred and Seventeen chemical shops. The submetro has a very good asphalted road network, with equally good telecommunication infrastructure. Water supply to the sub-metro is mainly by the Ghana Water company with sources from the Barekese and the Owabi water treatment plants. The sub-metro has high prevalence of water related disease, especially diarrhoea and dysentery, and it is among the hardest hit sub-metros, when there is shortages in water supply, due to its population size. (, KMA, 2015).

3.3 STUDY POPULATION

The study population were residents of the Bantama sub-metro who have attained the age of 15 years and above, and residing in houses which had been in existence six months and over.

3.3.1 INCLUSION AND EXCLUSION CRITERIA

Persons aged 15 years and above, residing in the Bantama sub-metro over the past 6 months were included in the study. On the other hand persons below 15 years were excluded from the study.

3. 4 SAMPLE SIZE CALCULATION

According to the Water and Sanitation Department of the Kumasi Metropolitan Assembly, 93.6 % of households in the Metropolis have access to improved water sources for drinking.

Assuming the population is normally distributed, at 95% confidence interval level and with a margin of error of 0.05, the sample size for the study was estimated from the equation below:

$$n = \frac{z^2 . pq}{d^2} \qquad n = \frac{1.96^2 \, p(1 - p)}{d^2}$$

Where n = estimated sample size

Z = reliability coefficient (95%) = 1.96

P = is the proportion of estimated households with improved drinking water source d = the error margin

q = 1-p

p = 0.5

d= 0.05

Therefore $$n = \frac{1.96^2 \times 0.5 \times 0.5}{0.05^2} = 299.9 \approx 300$$

An estimated sample size of 300 was considered. And with non-response rate of 10%, the final sample size was 330. Consent was sought from the respondents before they were interviewed.

3.5 SAMPLING TECHNIQUES

A simple random sampling was employed in selecting the houses for the study. All houses in the sub-metro that meet the inclusion criteria were numbered, the numbers were written on pieces of paper, folded to conceal their identity, the numbers were put together in a bowl and mixed , so that each of the houses will have equal chance of being selected. In all three hundred and thirty (330) units of numbers were randomly picked by students of

KNUST .And in each household at least 2 persons were interviewed. However, the Ghana water Company (Barekese and Owabi dams) were purposively sampled for the study.

3.5.1 TABLE SHOWING SUBURBS AND NUMBER OF HOUSES SAMPLED

SUBURBS IN THE SUBMETRO	NUMBER OF HOUSES COUNTED	NUMBER OF HOUSES SAMPLED
SANTASI	168	60
BANTAMA	184	65
PATAASI	122	55
SOUTH SUNTRESO	117	50
NORTH SUNTRESO	109	50
SOFOLINE	107	50

Source: Field data results (2016)

3.6 DATA COLLECTION TECHNIQUES AND TOOLS

Data collection was done by administering a questionnaire (both close and open ended) to collect some primary data from the selected households through a face to face interview. Then, from the individual households 300 samples of water were collected in to 50 ml units' sterile bottles and transported on ice in an ice pack specimen bags for testing at the Kumasi Polytechnic's microbiology laboratory. The samples collected were from Tap water (188), Boreholes (73), Hand Dug wells (35) and others (4). Analysis of the water samples were done within 24hrs upon collection.

3.6.1 PRE-TESTING

Pre-testing of the questionnaire was done in the Oforikrom Constituency of the Kumasi metropolitan Assembly. 65 questionnaires were administered, questionnaires were further edited based on the feedback from the pilot study. Key issues raised had to do with wording, clarity and sequencing of questions and were corrected before the final questionnaires were administered. Data from the pilot study were excluded from the final data.

3.7 STUDY VARIABLES

Based on the objectives of the study, variables such as age of the respondents, educational background, marital status, religion, occupation, sources of drinking water within the households, the most reliable source of water to the community, the medium used in fetching and storing water within the household and the degree (concentration) of microbial contamination of water within the household were considered.

3.7.1 DEPENDENT VARIABLE

The dependent variable of the study was the degree of microbial contamination (specifically Total coliforms and E.coli) of household water.

3.7.2 INDEPENDENT VARIABLES

Independent variables considered by the researcher were age and gender of the respondents, educational background, religion, marital status, sources of water to the household, the most reliable source of water, medium used in fetching and storing water.

3.7.3 STUDY VARIABLE TABLE

Objective	Dependent Variable	Independent Variable	Scale of Measurement	Indicators	Data collection Method	Type of statistical analysis
To identify the source(s) of household water within the Sub-metro	Sources of household water	Old rusty pipe lines, poor maintenance of bore holes/well Cracked casing Opening between the lid and casing Casing material Well age Well depth	Nominal	Frequency and proportion	Questionnaire	Descriptive And Inferential
To identify the most used /relied upon water source(s) by the people within the community	The most reliable source of water to the community/ household	Quantity and Quality of water, Availability and accessibility of water	Nominal			Descriptive And Inferential
To identify the degree of microbial contaminant (specifically E.coli and Total/Faecal coliforms) in the household water within the Community.		Well Stream Pond Dam Pipe borne Others	Nominal			Descriptive and Inferential

STUDY VARIABLE TABLE CONTINUATION

		Age, Sex Ethnicity Educational background Marital status Religious affiliation Occupation	continuous Nominal	Frequency and proportion	Questionnaire	Descriptive

3.8 DATA HANDLING

The data collected were checked for completeness and correctness. Collected data were cleaned and verified and copies kept by the principal investigator.

3.9 DATA ANALYSIS

All data from the questionnaire were entered in to SPSS software version 17.0, and Stata software version 11.0 for analysis. Microsoft Excel was also used to generate graphs after the analysis. Water samples from the individual sources within the study area was collected. Fecal and total coliform counts were performed using the standard membrane filtration technique. The 50 ml water sample was filtered using 0.45 mm pore size, 47 mm diameter filter membrane as described by the American Public Health Association, (APHA, 1998). A combination of the multiple tube technique and membrane filtration were employed and results expressed in cfu/100ml. Nutrient agar (NA) as a basal medium, MacConkey agar as a differential medium and Blood agar as a special medium were used to determine enteric bacteria. Escherichia coli are isolated by inoculating the sample in Bismuth green bile broth.

Statistical analysis were performed on the data. Aided by the data available, the quality of water from the various households were assigned weights to obtain some quantitative data, variables considered for the statistical analysis included the educational background of the respondents, gender, medium for storing water., locality or suburb and the degree of microbial contamination. This was to assess which variable were causing what effect.

3.10 ETHICAL CONSIDERATIONS

In line with the Helsinki Declaration, ethical clearance was sought from the committee on Human Research, Publication and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology (KNUST). Permission was also obtained from the Metropolitan Health Directorate of the Kumasi metropolitan Assembly .Consent was sought from the respondents before data and samples were collected and they were assured of confidentiality and anonymity of the information that would be provided.

3.11 ASSUMPTIONS OF STUDY

1. It was assumed that the study population had characteristics that are shared by the target population, therefore it would be representative of the larger population.
2. It was also assumed that answers that were provided by the respondents were exact and accurate.
3. It was also assumed that the WHO standards for portable/drinking water and that of Ghana Water Company are the same and have not changed since 2010.

3.12 LIMITATIONS OF STUDY

The study was limited by the water available within the household as of the time the research team collected the samples. This could potentially leave out some other water(s) used by the household hence depriving the researcher of some other information on the topic; thus, limiting the external validity of the results. Another limitation was the water that the respondents (households) permitted the research team to access, as of the time the research team visited the household. And some of water sources were identified by the answers provided by the respondents. Another limitation was that, the sources of water were sampled just once.

3.13 RELIABILITY AND VALIDITY OF STUDY FINDINGS

To ensure validity and reliability, the question guide was pre-tested in the Oforikrom constituency. The test-retest method was employed in the administering of the questionnaires at two different times to ensure the consistency of the results obtained. With a stable measure adopted, the results that were obtained after a repeated test were similar with little or no difference at all. Water samples were analysed based on Standard Methods for Examination of Water and

Wastewater (American Public Health Association, 1998). Double and in some cases triplicate samples were taken for every tenth sample. Results of such double and triplicate samples were same. All instruments and equipment used were calibrated and checked with known standards to ensure accuracy.

3.14 APPLICATION POSSIBILITIES OF STUDY FINDINGS

The findings of this study are likely to be considered by the Ghana Water Company in collaboration with the Kumasi Metropolitan Assembly (Directorate of Health) and the Ashanti Regional Health Directorate as plans are underway to achieve universal access to portable water by the year 2025 in Ghana.

CHAPTER FOUR

RESULTS

4.0 INTRODUCTION

This chapter details the findings of the study. 300 respondents in the Bantama sub-metro took part in the study and below are results obtained;

The presentation of the results was based on the objectives of the study, i.e

1. To identify the source(s) of household water within the Sub-metro.
2. To identify the most used /relied upon water source(s) by the people within the community
3. To assess the medium used by the people in fetching and/or storing water
4. To identify the type (if any) and the degree of microbial contaminant (specifically Total coliforms and E.coli) in the household water within the Community

4.1 DEMOGRAPHIC CHARACTERISTICS

The demographic characteristics included sex, age, educational background, marital status, religion, and occupation of respondents. A total of 300 respondents were interviewed.

TABLE 4. 1: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

PARAMETER	FREQUENCY (300)	PERCENTAGE
SEX		
MALE	125	41.7
FEMALE	175	58.3

AGE GROUP		
15 – 24	35	11.7
25 - 34	90	30.0
35 – 44	70	23.3
45 – 54	54	18.0
55 - 64	33	11.0
65 and ABOVE	18	6.0
MARITAL STATUS		
SINGLE	101	33.7
MARRIED	178	59.3
DIVORCED	12	4.0
COHABITATION	9	3.0
RELIGIOUS BACKGROUND		
CHRISTIAN	189	63.0
MUSLEM	107	35.7
TRADITIONALIST	4	1.3
OCCUPATION		
FARMER	33	11.0
TRADER	107	35.7
CIVIL/PUBLIC SERVANTS	72	24.0
OTHERS	88	29.3

Source: Field data results (2016)

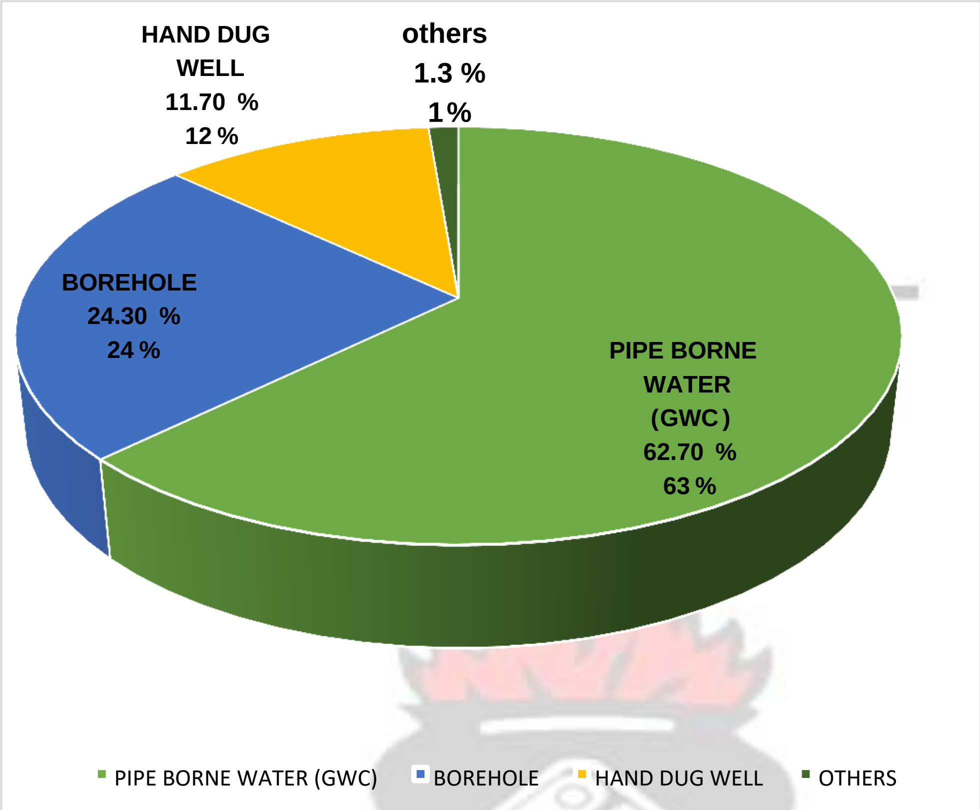
Table 4.1 above shows the demographic characteristics of the respondents. The data revealed that 175(58.3%) out of 300 respondents were females, age group of 25 – 34 were dominant (30%) amongst the respondents, followed by age group 35 –44. The data further revealed that 178 (58.3%) of the respondents interviewed were married, in relation to their religious background, greater number 189 (63.0%) were Christians, but a marginal number of 4(1.3%) were Traditionalist. When occupation of the respondents were assessed 107 (35.7%) were traders within the metropolis.

4.2 SOURCES OF WATER TO THE HOUSEHOLD WITHIN THE SUB-METRO

Sources of water to the households were identified, aided by the questionnaire. Three major sources of water to the households were identified, i.e. Pipe borne water from the GWCL 188(62.7%), water from privately owned Boreholes 73 (24.3%), Hand dug wells 35 (11, 7%) and other minor sources 4 (1.3%) such as springs and sachet water. These water sources also serve as sources of drinking water for the various households.

FIGURE 4.1: SOURCES OF WATER TO THE HOUSEHOLD WITHIN THE

SUB-METRO

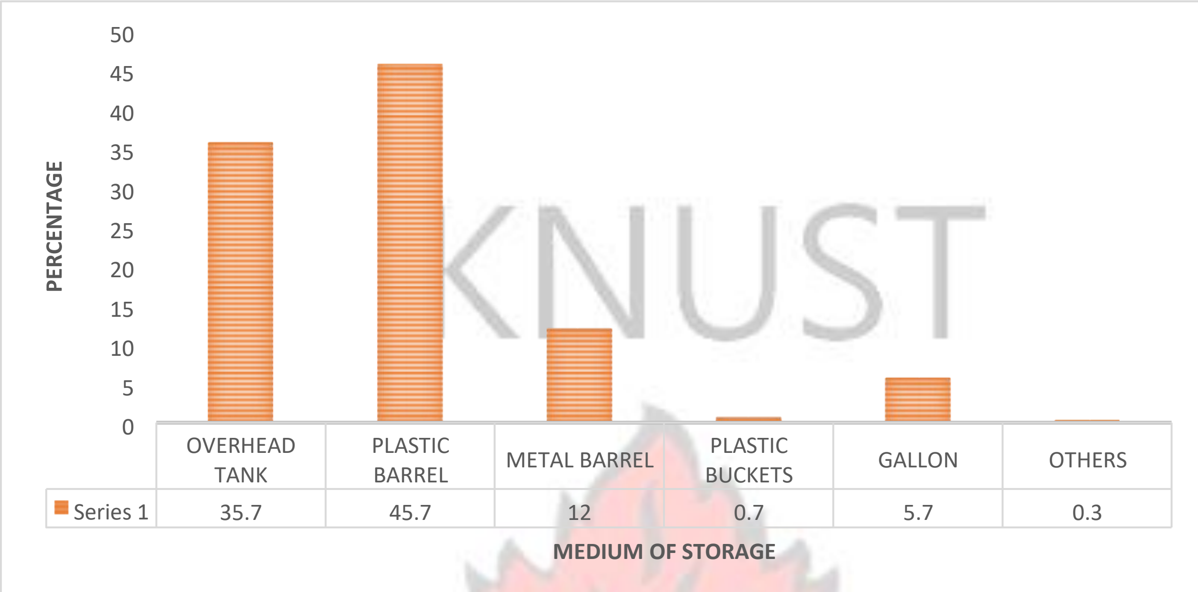


Source: Field data results (2016)

4.3: MEDIUM FOR WATER STORAGE IN THE SUB-METRO

Four media for water storage were identified by the researcher. Greater percentage (45.7%) of the respondents made use of plastic barrel in storing water, followed by overhead tanks. (35.7%), Metal barrel (12%) and in Gallons (5.7%). The level of protection against environmental pollutants of these storage mediums were also assessed.

FIGURE 4.2: MEDIUM FOR WATER STORAGE BY THE RESPONDENTS



Source: Field data results (2016)

TABLE 4.2: RELATIONSHIP BETWEEN RESPONDENT'S EDUCATIONAL BACKGROUND AND THEIR MEDIUM FOR WATER STORAGE

Education	Overhead Tank	Plastic Barrel	Metal Barrel	Plastic Bucket	Gallon	Others
Uneducated	12.8%	38.3%	34.0%	2.1%	12.8%	0.0%
Primary	0.0	45.5%	9.1%	0.0%	45.5%	0.0%
JSH	35.1%	40.5%	13.5%	2.7%	5.4%	2.7%
SHS	38.7%	49.5%	8.9%	0.0%	3.0%	0.0%
Tertiary	47.1%	47.1%	4.8%	0.0%	1.0%	0.0%

χ^2 (20, 300) = 93.143, p = 0.000.

TABLE 4.3: DEPENDACY BETWEEN LEVEL OF EDUCATION AND

MEDIUM FOR WATER STOAGE

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	93.143[a]	20	.000
Likelihood Ratio	73.688	20	.000
Linear-by-Linear Association	47.311	1	.000
N of Valid Cases	300		

The Pearson's Chi-square shows that there is dependency statistically between the level of education of the respondents and medium used in storing water. χ^2 (20, 300) = 93.143, p = 0.000.

TABLE 4.4: RELATIONSHIP BETWEEN GENDER AND MEDIUM FOR WATER STORAGE

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.163[a]	5	.526
Likelihood Ratio	5.264	5	.384
Linear-by-Linear Association	.051	1	.821
N of Valid Cases	300		

The statistical test employed (Pearson's Chi-square) showed no statistically significant relationship between gender and the choice of medium for water storage per the study. χ^2 (5, 300) = 93.144, p = 0.53. Therefore there is no dependency of gender on any particular medium for water storage according to this study.

4.4: RESULTS OF THE MICROBIAL ANALYSIS OF THE WATER SAMPLES

The microbial analysis results (after culturing) indicated the presence of *Total coliforms*and *E.coli* in some samples of water taken from the various households. There were however wide variations between the numbers of colonies counted per 100ml between the sources of water identified, and differences between the households. Moreover, the average *Total coliform* and *E.coli* density was relatively high in hand dug wells as compared to Pipe borne water and Boreholes.

Out of the 300 water samples tested, *Total coliforms*were detected in 19.7% (approx. 20%). The number of colony forming units per 100ml (cfu/100ml) counted of all these water samples exceeded the low risk WHO standard, i.e. (1 – 10 cfu/100ml) for drinking water. The cfu/100 ml counts for Hand dug wells ranged from 1.34×10^2 -

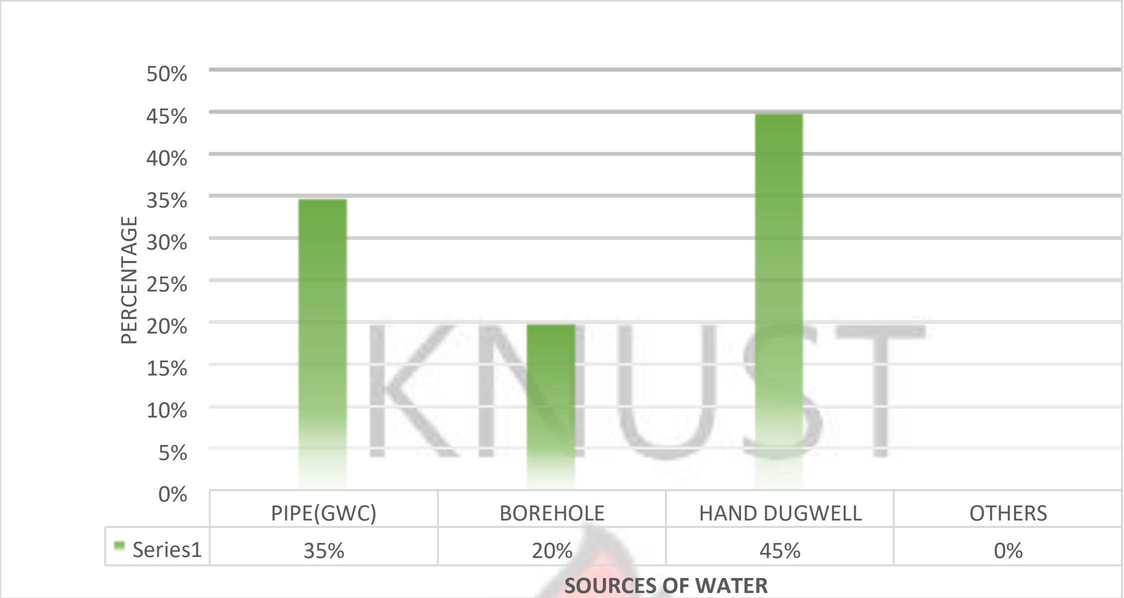
2.21×10^3 , 1.20×10 - 1.45×10^2 went for boreholes and Pipe borne water from GWCL recorded a range between $1.1 \times 10 – 1.31 \times 10^2$

Additionally, major variations of *Total coliforms* were also recorded in water within same water sources but from different suburbs or communities.

E.coli was also detected in 13.7 (approx. 14%) of the total samples tested. The number of cfu/100 ml counted maintained a similar pattern as above, with the exception of two samples which recorded values of 421 cfu/100ml and 446 cfu/100ml.

However, water sampled purposively from the Barekese and Owabi treatment plants (on site) recorded no *Total coliform* nor *E.coli* after microbial analysis were carried out.

FIGURE 4.3: TOTAL COLIFORM PRESENCE IN WATER SAMPLES FROM DIFFERENT SOURCES

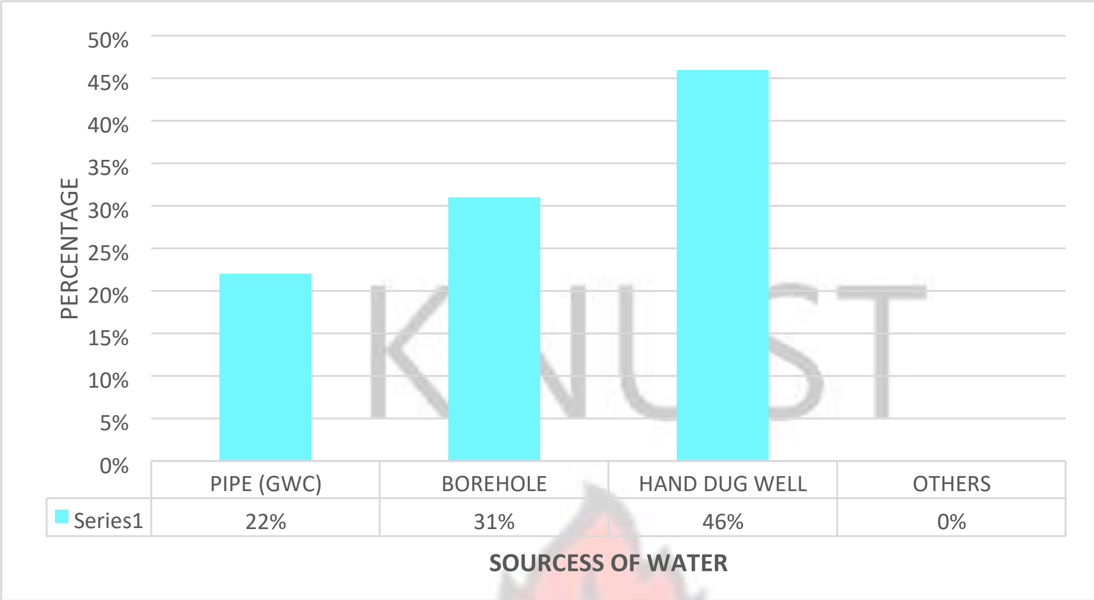


Source: Bacteriological data results (2016)

Presence of *Total coliform* were recorded in all the three major sources of water identified by the researcher within the sub-metro. Figure 4.3 above graphically displays the results.

FIGURE 4.4: *E.coli* PRESENCE IN WATER SAMPLES FROM DIFFERENT

SOURCES

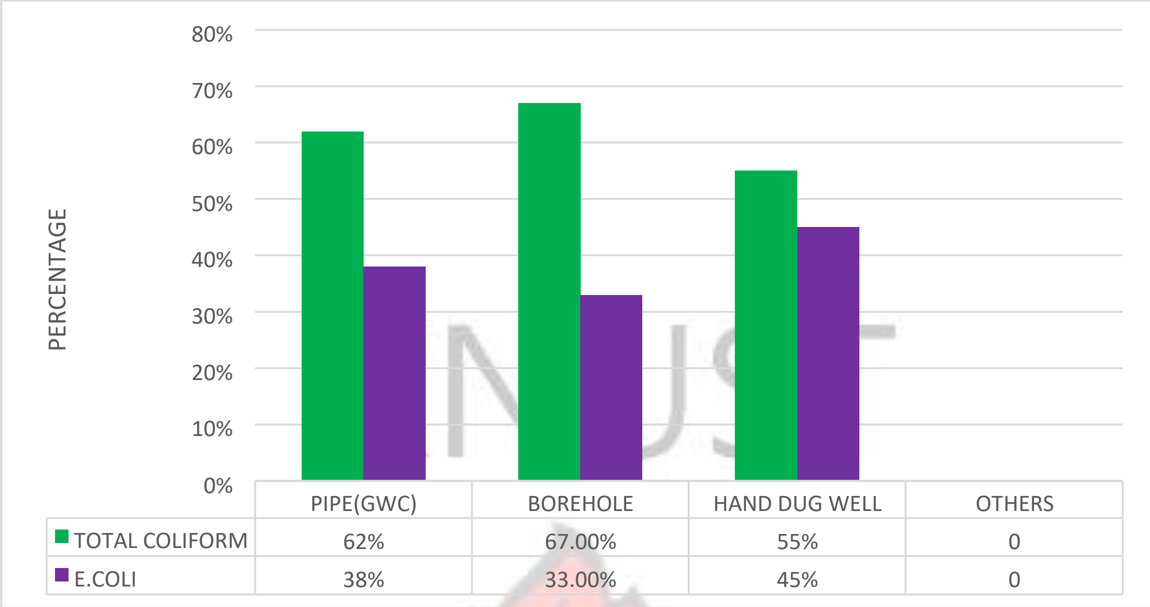


Source: Bacteriological data results(2016)

Figure 4.4 above displays graphically the results of the presence of *E.coli* in the major sources of water identified by the researcher

The presence of *E.coli* within the sampled water sources amounted to 13.7%, with contributions coming from all the major sources of water identified within the study area, a similar picture was observed with the *Total coliform*.

FIGURE 4.5 RELATIONSHIP BETWEEN *TOTAL COLIFORM* AND *E. COLI* IN SOURCES OF WATER



The correlation between *Total coliform* and *E. coli* counts was positive and significant (r = 0. 817, p < 0.04). *Total coliform* counts were significantly (p < 0.05) higher than those of E.*coli*. The general trend was that while densities of *E. coli* were lower than those of *Total coliform* for all the water sources, the trend in the number of cfu /100ml of *E. coli* increasing as those of *Total coliforms* increased was observed to be significant

TABLE 4.5: ANALYSIS OF VARIANCE (ANOVA) BETWEEN THE VARIOUS SUBURBS WITHIN THE BANTAMA SUB-METRO.

SUBURB		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Santasi	Bantama	-.16000	.19370	.409	-.5412	.2212
	South Suntreso	.40000*	.19370	.040	.0188	.7812
	Patasi	-.12000	.19370	.536	-.5012	.2612
	North Suntreso	.14000	.19370	.470	-.2412	.5212
	Sofoline	.36000	.19370	.064	-.0212	.7412
Bantama	Santasi	.16000	.19370	.409	-.2212	.5412
	South Suntreso	.56000*	.19370	.004	.1788	.9412

	Patasi	.04000	.19370	.837	-.3412	.4212
	North Suntreso	.30000	.19370	.123	-.0812	.6812
	Sofoline	.52000*	.19370	.008	.1388	.9012
South Suntreso	Santasi	-.40000*	.19370	.040	-.7812	-.0188
	Bantama	-.56000*	.19370	.004	-.9412	-.1788
	Patasi	-.52000*	.19370	.008	-.9012	-.1388
	North Suntreso	-.26000	.19370	.181	-.6412	.1212
	Sofoline	-.04000	.19370	.837	-.4212	.3412
Patasi	Santasi	.12000	.19370	.536	-.2612	.5012
	Bantama	-.04000	.19370	.837	-.4212	.3412
	South Suntreso	.52000*	.19370	.008	.1388	.9012
	North Suntreso	.26000	.19370	.181	-.1212	.6412
	Sofoline	.48000*	.19370	.014	.0988	.8612
North Suntreso	Santasi	-.14000	.19370	.470	-.5212	.2412
	Bantama	-.30000	.19370	.123	-.6812	.0812
	South Suntreso	.26000	.19370	.181	-.1212	.6412
	Patasi	-.26000	.19370	.181	-.6412	.1212
	Sofoline	.22000	.19370	.257	-.1612	.6012
Sofoline	Santasi	-.36000	.19370	.064	-.7412	.0212
	Bantama	-.52000*	.19370	.008	-.9012	-.1388
	South Suntreso	.04000	.19370	.837	-.3412	.4212
	Patasi	-.48000*	.19370	.014	-.8612	-.0988
	North Suntreso	-.22000	.19370	.257	-.6012	.1612

Source : Field data results (2016)

The table 4.5 above shows the results of Analysis Of Variance (ANOVA) between the group means of the quality of water from six different suburbs.

The statistical test employed revealed a statistically significant difference between groups as determined by the one -way ANOVA (F (5, 294)= 3.040, p=0.011). ALeast Significant Difference (LSD)post hoc test revealed that the quality of water from Santasi (3.88 ± 1.38, p = 0.04) was statistically significantly different from that of South Suntreso(3.5 ± 0.97). Similar observations were made for Bantama (4.04 ± 0.81, p = 0.004) and South Suntreso (3.48 ± 0.97); Bantama (4.04 ± 0.81, p = 0.008) and Sofoline (3.52 ±0.97); South Suntreso (3.48 ± 0.97, p = 0.008) and Patasi (4.00 ± 057) and Patasi (4.00 ± 057, p = 0.01) and Sofoline (3.52 ±0.97).

However, there were no statistically significant difference in the qualityof the water between the following suburbs: Sofoline and Santasi; Patasi and North Suntreso; North Suntreso and Sofoline; Santasi and South Suntreso; Santasi and Bantama; Santasi and Patasi; NorthSuntreso and South Suntreso;Sofolineand South Suntreso; Bantama and Patasi; Bantama and North Suntreso. (Table 4).

TABLE 4.6: ANALYSIS OF VARIANCE (ANOVA) BETWEEN THE SOURCES OF WATER IN SIX DIFFERENT SUBURBS WITHIN THE BANTAMA SUBMETRO.

Sources of water to household		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Pipe	Borehole	.04882	.12668	.700	-.2005	.2981
	Hand dug well	1.15410*	.16911	.000	.8213	1.4869
	Others	.17553	.46416	.706	-.7379	1.0890
Borehole	Pipe	-.04882	.12668	.700	-.2981	.2005
	Hand dug well	1.10528*	.18886	.000	.7336	1.4770
	Others	.12671	.47171	.788	-.8016	1.0550
	Pipe	-1.15410*	.16911	.000	-1.4869	-.8213

Hand dug well	Borehole	-1.10528*	.18886	.000	-1.4770	-.7336
	Others	-.97857*	.48483	.044	-1.9327	-.0244
Others	Pipe	-.17553	.46416	.706	-1.0890	.7379
	Borehole	-.12671	.47171	.788	-1.0550	.8016
	Hand dug well	.97857*	.48483	.044	.0244	1.9327

The table 4.6 above shows the results of Analysis Of Variance (ANOVA) between sources of water in terms of the quality of water from six different suburbs within the Bantama sub-metro.

The result revealed a statistically significant difference between groups as determined by the one -way ANOVA ($F(3, 294) = 15.907$, $p=0.000$). A Least Significant Difference (LSD) post hoc test revealed that the quality of water from Pipe Born Water (3.93± 0.84, p = 0.000) was statistically significantly different from that of Hand Dug Wells (2.77± 1.17). Similar observations were made for Boreholes (3.88 ± 0.99, p = 0.000) and Hand Dug Well (2.77 ± 1.17); Hand Dug Wells (2.77 ± 1. 17, p = 0.044) and Others (3.75 ±0.500) However, there were no statistically significant difference in the quality of the water between the following sources: Pipe Born water and Borehole; Pipe Born water and others; Borehole and Others (Table 6)

Further inferential statistics (ANOVA) was carried out to analyse the existence or otherwise of differences in terms of the quality of water between the suburbs. The findings were statistically significant with a p value of 0.011. The table above shows the statistical variations between the suburbs in the sub metro.

TABLE 4.7: ANALYSIS OF VARIANCE OF THE QUALITY OF WATER

BETWEEN SUBURBS IN THE BANTAMA SUBMETRO

Rating	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.257	5	2.851	3.040	.011
Within Groups	275.780	294	.938		
Total	290.037	299			

However, this test does not reveal which of the pairings are significantly different. In view of this, a multiple comparison test of Least Significance difference (LSD) was adopted to assess the quality of water between the various suburbs within the sub metro. This analysis also revealed statistically significant differences in mean ratings between the suburbs with a p value of 0.038 ($P < 0.05$).

TABLE 4.8: RATING OF SUBURBS IN TERMS OF QUALITY OF WATER

Rating	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	Between-Component Variance
					Lower Bound	Upper Bound			
Santasi	50	3.8800	1.37974	.19512	3.4879	4.2721	1.00	5.00	
Bantama	50	4.0400	.80711	.11414	3.8106	4.2694	2.00	5.00	
South Suntrso	50	3.4800	.97395	.13774	3.2032	3.7568	1.00	5.00	

Patasi	50	4.0000	.57143	.08081	3.8376	4.1624	3.00	5.00	
North Suntreso	50	3.7400	.92162	.13034	3.4781	4.0019	1.00	5.00	
Sofoline	50	3.5200	.97395	.13774	3.2432	3.7968	1.00	5.00	
Total	300	3.7767	.98490	.05686	3.6648	3.8886	1.00	5.00	
Model			.96852	.05592	3.6666	3.8867			
				.09749	3.5261	4.0273			.03827

CHAPTER FIVE

DISCUSSION OF STUDY FINDINGS

5.0 INTRODUCTION

This chapter discusses the findings of the study based on the study objectives. The main objective of this study was to assess the microbial contents of household water specifically Total coliform and E.coli within the Bantama sub metro.

5.1 CHARACTERISTICS OF RESPONDENTS

The study revealed that out of the 300 respondents interviewed, majority (58.3%) were females, the highest age was recorded to be 76 years; the lowest age was 15 years. Majority of the respondents were in the age group 25 – 34 years (30%); indicating broader consultation and involvement of females within the ages of 25 -34 in future interventions and policies in relation to water and sanitation, if greater impact is to be derived. Most of the respondents were Christians (63%), with a marginal few being traditionalist. This also presupposes that in reaching out to the masses with educational materials and other relevant information which could impact positively on health and welfare of the people, the Christian community as well as their religious leaders , could be very instrumental in that drive. Greater number of the respondents were married with higher level of education; Majority of the respondents were traders. This findings agrees with 2010 population and housing census report of Statistical service of Ghana, which indicated more females than males in Kumasi (GSS, 2012).

5.2 SOURCES OF HOUSEHOLD WATER IN THE STUDY AREA

Three major sources of household water and a minor one were identified according this study. These were Pipe Borne water from Ghana Water Company Limited (GWCL), approximately 63%, 24% for Bore holes, hand dug wells 12% and 1% coming from a spring, corroborating with Akoto and Abankwah who identified similar sources of water in a research conducted on microbial quality and metal levels in sources of water in some peri-urban communities in Kumasi, Ghana. These findings were also consistent with Mosley as well as Nilsson and Pettersson in similar research done on drought impact on water quality of fresh water systems. Though recent reports and studies show that access to safe drinking water is improving in Ghana, Ghana Water Company Limited(GWCL) currently only meets the demands of about 60% of urban and peri-urban residents (Nyarko *et al.*, 2013; JMP, 2013), indicating a deficit of about 40% in demand for water. However, the existing water bodies are under constant threat of pollution by activities of illegal mining and illegal disposal of industrial and domestic waste. (Kpan *et al.*, 2014), creating the need to jealously protect these water bodies by regulating authorities and enforcing agencies such as the Ghana Water Resources Commission (GWRC), the Ghana water company Limited (GWCL), the Environmental Protection Agency (EPA) and the Metropolitan and Municipal assemblies if these gains were to be sustained and progressed, Hence , the current policy introduced by the current government of the New Patriotic Party under the leadership of his excellency President Akufo Ado that bans galamsey activities of any form is welcoming and a step in the right direction else dwindling effects of the Millennium Development Goals(MDGs) on water and sanitation looks eminent.. (Adank *et al*., 2013; Morinville, 2014).

5.3 MEDIUM FOR WATER STORAGE BY THE RESPONDENTS

The study established that Plastic Barrels /drums, overhead plastic tanks, Metal Barrel/drum and Plastic gallons /jerry cans, are the medium for water storage. This findings is consistent with findings of a similar research carried out by Peloso and Morinville (2014) in Accra Ghana on the topic ―Chasing for Water': Everyday Practices of Water Access in Peri Urban Ashaiman, Ghana. However, there are other school of thought with the argument that plastic water tanks and bottles pose some health risk due to leaching of chemicals used in manufacturing these plastics into drinking water when exposed to higher temperatures, (Dawn, 2015), That notwithstanding, these water storage medium remain the most widely used water storage material according to this and other studies, Peloso and Morinville (2014). Similar reports and health concerns have been raised by National Institute of Environmental Sciences (USA) and a publication in the Journal of Water and Health (UK), however, manufactures of the tanks have contrary claims, (Dawn, 2015). Currently there is no policy on what medium or material to use or not to use for water storage in the country. Inspite of the various materials available for water storage, (wood, clay (earthen pots), stone, concrete, steel, plastics (polyethylene, polypropylene) and fiberglass), there is still the need to determine which material is suitable for which geographical region and why, indicating a knowledge gap that needs to be filled. Further studies in this subject area is needed to the put to rest the uncertainty surrounding the use of these plastic water storage medium and to inform future policy formulation.

5.3.1 RELATIONSHIP BETWEEN RESPONDENT'S EDUCATIONAL BACKGROUND AND THEIR MEDIUM FOR WATER STORAGE.

The study explored the relationship between respondents‘ educational background and the choice of medium for water storage. (Table 2).The relationship were statistically significant. χ^2 (20, 300) = 93.143, p = 0.000.

The respondents with higher education were more likely to use storage medium that had proper protection against contamination at the point of storage and use. (I.e. overhead tanks and barrels/drums with proper covering limiting access to environmental pollution or contamination). The opposite is true for those with lower level of education, corroborating Arthur (2010) who identified a similar situation in a research conducted on the relationship between sanitation and hygiene as against level of education in Bogoso ,Ghana. Indicating a need to intensify hygiene promotion and education amongst the basic school to the local communities to sensitize them about health implication of not protecting their drinking water sources.

5.3.2 RELATIONSHIP BETWEEN GENDER AND MEDIUM FOR WATER STORAGE

The researcher further explored the relationship between gender and medium for water storage, (Table 4). The findings were statistically insignificant χ^2 (5, 300) = 93.144, p = 0.53, This presupposes that no gender is skewed towards any particular medium for storing water according to this study, could be due to the fact that most households were made up of both sexes sharing the same amenities with common access.

On the contrary, a large and growing body of literature suggests that women and men often have differentiated relationships to water access, uses, knowledge, governance, and experiences (Harris *et al*., 2016) . However, Buechler and Hanson (2015) argue that these differentiated relationships could be mediated through gendered labour practices within the household, community level and sociocultural expectations related to notions of masculinity and femininity as well as intersectional differences such as income and so forth. This stems from cross-national analyses and multiple case studies that argued that women are most often responsible for water procurement for domestic uses (bathing, cooking, cleaning, and drinking) and that women in particular often spend significant time on this task (Galvin, 2014; Singh *et al*., 2015). This has led water policy communities to focus on women as primary purveyors of water and to recognize that adverse water conditions such as water scarcity and drought may particularly affect women and girls in terms of work burden or responsibilities.

5.4 MEDIUM USED IN FETCHING WATER WITHIN THE BANTAMA SUB METRO.

The findings of this study suggest buckets, gallons (plastic jerry cans) and head pans as the main medium used in fetching water in the study area. This is consistent with what has been found in the literature. (WSUP, 2015). The choices of these medium could be attributed to a number of reasons, thus, the relative density of water, the distance of travel, the convenience of fetching and transporting water whilst minimizing loses could be cited. However, exposure to contaminants or pollutants on the use of the buckets and head pans, from the point of fetching through storage and point of use, due to wider opening, demands further probing for future policy formulation and implementation.

5.5 MICROBIAL ANALYSIS OF HOUSEHOLD WATER WITHIN THE BANTAMA SUB-METRO.

The study revealed the presence of microbial indicator organisms (*Total coliform and E.coli*) in all the major sources of water identified, (Figure 5 & 6) with high bacterial densities above the WHO‘s low risk levels of 1- 10 cfu/100ml. The presence of the *Total coliform and E.coli* is an indication of faecal contamination from sewage systems, and human or animal waste, making the water not fit for drinking. This finding complements what were reported by Kumpel and Nelson, (2016) . Water contaminated with *E.coli* has been known to be the major cause of diarrhoea and dysentery (Abia *et al*, 2017), claiming lives of most children and some adults. This calls for effective integrated interventions to curb the contamination of these sources of water to save lives.

However, statistically significant variations in quality of water were observed between the sources of water, ($F (3, 294) = 15.907$, $p=0.000$), (Table 6). This could be attributed to the level of protection against contamination and care of these water sources. This replicates findings of similar research conducted by (Abia *et al.*, 2017 in South Africa and Ashbolt, 2015) in England and (Bain *et al*,. 2014) in Nigeria. It was revealed that most Hand dug wells are not well protected as compared to pipe borne water (Tap water) and Boreholes, making it most vulnerable to run off water carrying faecal contaminants. Boateng *et al.*, (2015) also reported that private water supplies suffer immense microbiological contamination due to their non-compliance to potable water supply regulations. Emenike *et al.*,(2017) recommended the establishment of a policy guide line aiming at focused intervention in protecting drinking water sources, but little seems to have been done with the passing of time.

Similar statistically significant variations in the quality of water were recorded between the six suburbs where the study was conducted ($F (5, 294) = 3.040$, $p=0.011$), (Table

5). This could also be attributed to a number of reasons. According to Fisher *et al*., (2015), factors that could influence variations of such include; varying hygiene behaviors of households, sanitation conditions of the communities under study, and siting of septic tanks in the area under study. In this study, wrong sitting of septic tanks was observed by researcher during the administration of the questionnaires, correlating with research findings by Igbinovia *et al*, .2016 and Owusu-Sekyere *et al*., 2014 that wrong siting of septic tank were the focal and principal source of groundwater contamination by bacteria and viruses.

This calls for enforcement of existing by- laws which demands minimum horizontal setback distances from sewerage systems and septic tanks to water sources to be 30 and 15 metres, respectively. Further studies is encouraged on siting of septic tanks and wells /boreholes in households and communities and its impact on drinking water sources, findings of which will add to existing knowledge and influence policy formulation and implementation in the Kumasi metropolitan assembly and its environs.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 INTRODUCTION

In this study, the researcher used data from 300 household in six suburbs/communities of the Bantama sub-metro in Kumasi metropolitan Assembly, Ghana to assess the microbial contents of water among others in those households. Understanding the factors that affect the quality of water and its implication on the general wellbeing of the citizenry is key for policy formulation and interventions to mitigate any such occurrences.

6.1 CONCLUSION

6.1.1 SOURCES OF WATER

The study identified Pipe Borne Water (tap water) from Ghana Water Company, Boreholes and Hand dug wells as main sources of water in the study area.

6.1.2 THE MOST RELIABLE SOURCE(S) OF WATER

Boreholes and hand dug wells were more reliable in terms of availability and accessibility than Pipe borne water.

6.1.3 MEDIUM USED IN FETCHING AND STORING WATER

Buckets, Gallons (Jerry cans) and head pans were the main medium used in fetching water , as storage were by plastic barrels/drums, plastic overhead tanks, Metal barrels/drums and plastic gallons(jerry cans) according to this study.

6.1.4 MICROBIAL CONTENTS OF THE WATER

Total coliform and E.coli were detected in all sources of water identified with bacteria densities higher and above the WHO's low risk levels. Indicating faecal contamination and eminent health risk. Implications are that these waters were not fit for drinking and a need for good environmental and hygiene practices coupled with strict application of existing laws and supervision by agencies and bodies authorized by law could be beneficial, if the millennium development goals were to be achieved.

6.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are drawn;

6.2.1 SOURCES OF WATER

Sources of water should be jealously protected by bodies and agencies mandated by law to do so such as Ghana Water Resources Commission ,(GWRC); The Ghana Water Company Limited,(GWCL) ;The Environmental Protection Agency,(EPA) ; and The Metropolitan and Municipal Assemblies , then offenders severely punished to serve as deterrent to others. The Public Health Units of The Metropolitan Health Directorate should intensify health education and Individuals encouraged to take charge of their health in general by modifying lifestyles and habits, that predispose them to health risks of which water and sanitation is paramount.

6.2.2 THE MOST RELIABLE SOURCE(S) OF WATER

Regular distribution or sale of subsidized chlorine tablets to those using Borehole and Hand dug well is recommend to ensure some level of treatment of the water from these sources before it gets to the point of use .

The Kumasi Metropolitan Assembly in collaboration with the sub-metros, NGO‘s, Religious organizations ,traditional leaders and the community at large should design strategies for a coordinated and organized interventions to deal with issues of sanitation in the metropolis. This will impact positively on the environmental health and reduce the rate of contamination of our water bodies.

6.2.3 MEDIUM USED IN FETCHING AND STORING WATER

The researcher recommends proper covering and regular cleaning of the medium identified for both fetching and storage. This will reduce the level of exposure to contaminating agents from the source of the water to the point of use.

6.2.4 MICROBIAL CONTENTS

6.2.4.1 Regular sampling and testing of household water by the Ghana Water Company limited and other entities capable of testing, is recommended. This will alert the providers and consumers of any danger that may arise and the necessary interventions put in place to arrest it.

6.2.4.2 The Ministry of Sanitation and Water Resources and Works and Housing in collaboration with the district assemblies, should intensify sanitation and health education in the country, from the grass roots. This will ensure good sanitation practices which will reduce the burden of water borne disease on the country as a whole.

6.2.4.3 The era of sanitary inspectors by the metropolitan assemblies should be revisited to check the menace of improper waste and refuse disposal.

6.3 AREAS FOR FURTHER RESEARCH

6.3.1 This research concentrated its effort on the microbial contamination of household water (specifically on E.coli and Total coliforms,) further research is encouraged in other pathogenic microorganism in household water apart from the aforementioned.

6.3.2 There is no much information as to what material is suitable for water storage in what geographical region and why the choice, the researcher proposes further research in this area as well.

6.3.3 Further studies is encouraged on siting of septic tanks in relation to wells and boreholes in households and communities and its impact on these drinking water sources.

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APPENDICES

APPENDICE A

QUESTIONNAIRE

KWAME NKRUAH UNIVERSITY OF SCIENCE AND TECHNOLOGY/DEPARTMENT OF HEALTH EDUCATION AND PROMOTION / SCHOOL OF PUBLIC HEALTH

Research Title:

QUESTIONNAIRE FOR ASSESSING THE MICROBIAL CONTENTS OF HOUSEHOLD WATER IN THE BANTAMA SUB-METRO IN THE KUMASI METROPOLITAN ASSEMBLY, GHANA

Introduction

Good morning/afternoon. I am a student at School of Public Health, KNUST. I will be conducting several meetings with people like you in Bantama sub metro to find out your views and ideas about "(Microbial contents of household water in the sub metro) ***".*** *Your opinions are highly essential at the same time vital as they will help us to improve the kind of service to the metropollis. Whatever you say will be treated confidential, so feel at ease to express your candid opinion. Be assured that your responses will not in any way be linked to your identity. You are kindly requested to answer the questions below by indicating a tick or writing the appropriate answer when needed.*

THANK YOU

Date of Interview: ………………………………………………………………… SECTION A:

Socio-demographic characteristics of respondents

1. Suburb……………………………………………………………………………..
2. Age: 11 – 20 [ ] 21 – 30 [ ] 31 – 40 [ ] 41 – 50 [ ] 51-60 [ ] 61-70 [ ]
3. Sex: Male [ ] Female [ ]
4. Educational Background: Primary[ ] JSS[ ] SHS [ ] Tertiary[ ] Noneducated [ ]
5. Marital status: Married [ ] Single [ ] Divorced [ ] Other please specify ……………..
6. Religious Affiliation: Christian [ ] Muslim [ ] Other please specify…………………….
7. Occupation: Farmer [ ] Trader [ ] Civil/Public servant [ ] Other please specify………......

SECTION B:

8. Which is your major source of water to the house hold

   GWC (Pipe) [ ] Bore Hole [ ] Hand dug well [ ] Other, please specify……….……….

9. Is the above the source of drinking water for the household Yes [ ] No [ ] 10. When the source above (8) is not readily available, which is the next option available for the household? Rain [ ] Stream [ ] Pond [ ] Dam [ ] others specify [ ]…………………

SECTION C:

11. Which of the source(s) of water is/are most available to the household? GWC (Pipe) [ ] Mechanized Bore Hole [ ], Hand dug well [ ] Other, please specify…………

12. Which source(s) of water is/are easily accessible to the household?

GWC (Pipe) [ ] Mechanized Bore Hole [ ], Hand dug well [ ] other, please specify…………

13. Which source(s) is/are most reliable source(s) of water to the household/community?

GWC (Pipe) [ ] Mechanized Bore Hole [ ], Hand dug well [ ] other, please specify…………

14. Which of the source(s) is/ are most used by the household/community?

15. GWC (Pipe) [ ] Mechanized Bore Hole [ ], Hand dug well [ ] other, please specify…………

SECTION D:

16. Do you store water in the house? Yes [ ] No [ ]
17. In what do you store the water? Overhead Tank (E.g. polytank) , Plastic Barrel , Iron Barrel, Plastic Bucket, Gallons , Other, please specify Plastic Buckets, Galvanized Buckets, Gallon
18. Is the storage medium covered? Yes [ ] No [ ]
19. How long does the water stay in the storage medium?
20. What do you use in fetching the water? Bucket, Gallon, Other, please

specify………………..

21. Have you noticed any changes in the taste of the water you use ?

Yes [ ] No [ ] Do not Know [ ]

22. Have you noticed any changes in the appearance of the water used in the household ?

Yes [ ] No [ ] Have No Idea [ ]

23. Do you see any unusual particles or any foreign material in the water?

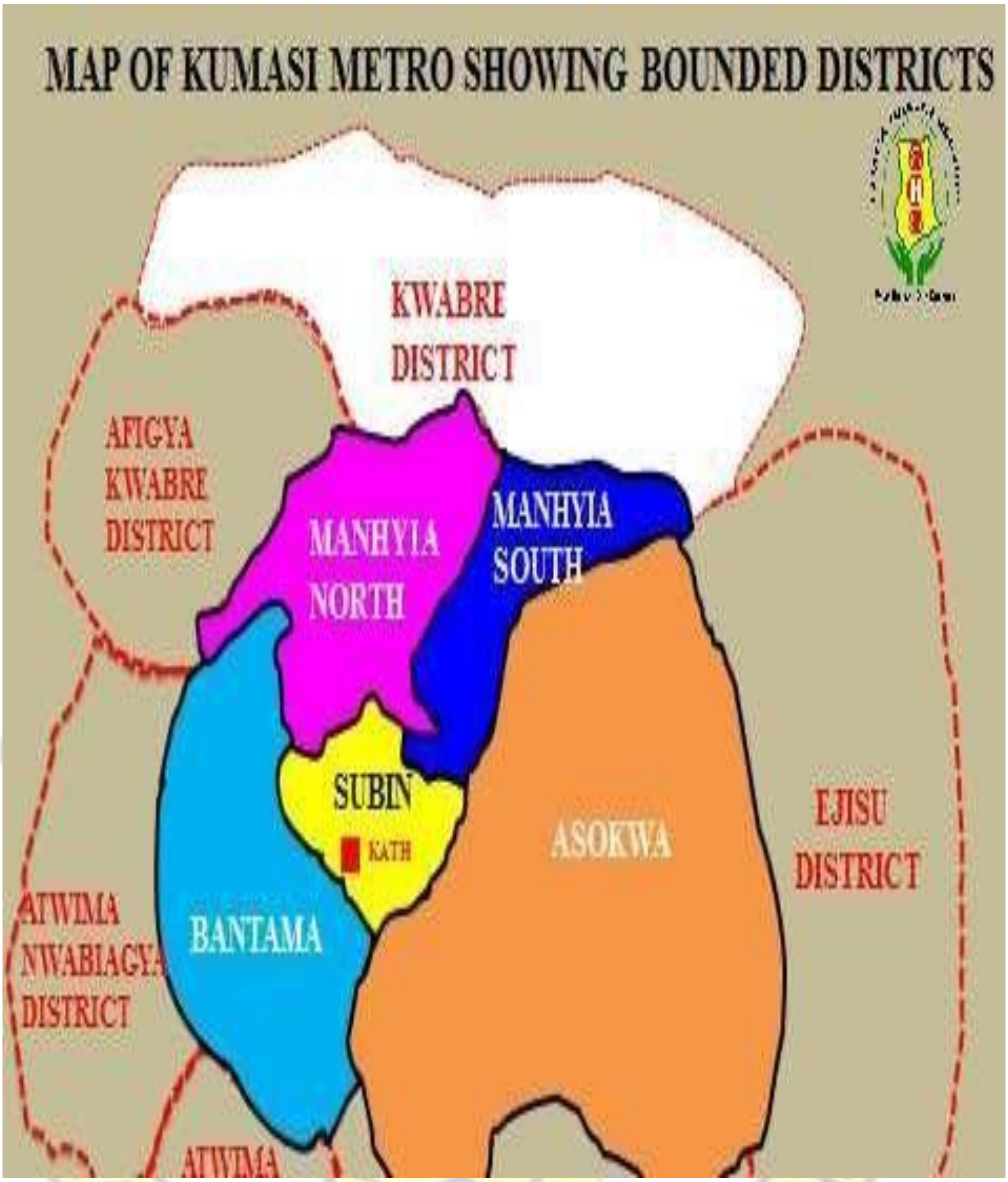
Yes [ ] No [ ]

24. What is your general impression about the water used in the household?

Excellent [ ] Very Good [ ] Good [ ] Fairly Good [ ] Poor [ ] Don't know [ ]

APPENDICE B

MAP OF KUMASI METRO



Map has not been updated with Asokore Mampong Municipal but it occupies a part of Manhyia South and Asokwa Sub-metro