PRESBYTERIAN UNIVERSITY COLLEGE, GHANA

FACULTY OF DEVELOPMENT STUDIES

DEPARTMENT OF ENVIRONMENTAL AND NATURAL RESOURCES MANAGEMENT

THE EXISTING LINKAGES OF HOUSEHOLD WATER QUALITY AND SANITATION SYSTEMS AT DENU IN KETU SOUTH MUNICIPALITY, GHANA

A dissertation submitted to the Department of Environmental and Natural Resources Management of the Faculty of Development Studies, Presbyterian University College, Ghana in partial fulfillment of the requirements for the award of Master's degree in Environmental Health and Sanitation

BY

CYRIL AYIVOR

SEPTEMBER 2020

DECLARATION

Candidate's Declaration

I hereby declare that this dissertation is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Name: Cyril Ayivor

Candidate's Signature: ……………………………..…… **Date**: …………….

Supervisor's Declaration

I hereby declare that the preparation and presentation of the dissertation were supervised in accordance with the guidelines on supervision of project work laid down by the Presbyterian University College, Ghana.

Name: Dr. Albert Allotey

Supervisor's Signature: …………………………… **Date**: …………………..

ABSTRACT

The study sought to investigate the household water quality & sanitation systems. The data gathered (questionnaire and laboratory analysis) were analyzed using Microsoft excel. The study revealed that the main water sources of the respondents was hand-dug/open well representing 91% and the least water sources was borehole/well with hand pump of 9%. The location of the main sources of water; 88% were within the compound, 9% were outside the compound/yard and 3%. For the reasons for the location of the main sources of water; 66% just decide to site anywhere while 34% were constructed by contractors. Majority of the respondents use pit latrine of 20(39%), KVIP/VIP of 16(31%), Flush/WC toilet with septic tank of 13(26%) and Flush/WC toilet with biofilm/digester of 2(4%). For the setting of the toilet facility; 38(76%) just decided to site anywhere, 8(16%) were site by Environmental officer and 4(8%) were site by contractor. For the location of the liquid effluent, 82% were buried underground and 18% were discharged on the land surface. The values of pH ranged from 4.893 to 5.647. Site E recorded the highest value of 5.647 and Site A recorded the lowest of 4.893. Turbidity values ranged from 1.56 to 9.85. Again, Site C recorded the highest of 9.85 and Site D recoded the lower of 1.56. EC ranged from 151.10 µS/cm to 358.37 µS/cm. The highest value was recorded by Site B of 358.37 µS/cm and the lowest by Site D of 151.10 µS/cm. TDS ranged from 79.78 to 184.24. The highest value was recorded by Site B of 184.24 and the lowest by Site D of 79.78. Nitrate ranged from 0.1544 to 0.3667. The highest value was recorded by Site B of 0.3667and the lowest by Site E of 0.1544. Phosphorus ranged from 0.0100 to 0.04063. The water and sanitation

programme of the Municipal Assembly should enforce by-laws on the minimum lateral distance of 20 m between a latrine and well water.

ACKNOWLEDGEMENTS

This research work will not have been completed without acknowledging the assistance received from individuals who have contributed in diverse ways towards the successful outcome of it.

I want to sincerely express my greatest appreciation to my supervisor, Dr. Albert Allotey for the time and energy spent in guiding me to come out with this research work.

I wish to also thank all those who were around me for their support and encouragement.

DEDICATION

To my dear wife Mrs. Mercy Ayivor,

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Access to safe drinking water plays an important role in human life related to health. Recently, the United Nations (UN) stated that safe and clean drinking water is a human right. About 748 million people lack access to improved sources of drinking water (WHO, 2014). Of these people, about 173 million get water from untreated surface water and more than 90% live in rural areas. So one of the big problems now is to overcome the gap of proper drinking water supply between urban and rural area (WHO, 2014).

A large proportion of the World's people do not have access to improved or microbiologically safe sources of water for drinking and other essential purposes (WHO, 2002). About 2.1 billion people globally lack access to safe drinking water at home (WHO, 2017). Although drinking water coverage has increased worldwide, access to reliable water quality is still a challenge. Poor water quality bears the risk to transport and spread diseases related to water. The problem may not be limited to untreated surface water, but may also arise from improved water sources with poor water quality. WHO (2014) stated that there was no assurance that people who get water from an improved source will get it free of contamination. One of the studies also showed that about 1.8 billion people get water from a source that is already faecally contaminated, which can cause cholera, enteric fever, and many other acute and chronic diseases (Bain *et al.*, 2014; Jessoe, 2013; Szabo & Minamyer, 2014).

Consumption of unsafe water continues to be one of the major causes of the 2.2 million water related disease deaths occurring annually, mostly in children (WHO/UNICEF, 2000). Diarrhoeal diseases kill an estimated 2.5 million people each year, the majority being children under 5 years (Kosek et al. 2003). An estimated 4 billion cases annually account for 5.7% of the global burden of disease and place diarrhoeal disease as the third highest cause of morbidity and sixth highest cause of mortality (Pruess et al. 2002). Water safety and quality are fundamental to human development and well-being. Providing access to safe water is one of the most effective instruments in promoting health and reducing poverty (WHO, 2017).

Water could be polluted through waste water, refuse and onsite disposal sanitation, which includes septic tanks and pit latrines. In Malawi wells were found to be more contaminated with *E. coli* bacteria than boreholes, the boreholes, on the other hand, were found to contain fewer pathogens at source compared to household level (Kanyere *et.al*, 2012). In India Shivendra and Ramaraju (2015) concluded that pit latrines and septic tanks are common modes of on-site sanitation that are sources of groundwater pollution. Improper wastewater disposal contaminates groundwater resulting in the spread of water-related diseases such as typhoid, cholera, dysentery (Kyakula *et al.*, 2015). Work by Sorenson *et al*. (2015) indicated that 18% of water supplies contained faecal coliforms, 91% of which were located within 10 m of a toilet and 58% had faecal coliforms above the detection limit, and sanitary risk scores were high. Septic tanks could contribute to groundwater pollution, particularly their density and layout. Septic tanks contribute the largest volume of wastewater, 800 billion gallons per year to the subsurface, and are most frequently reported cause of groundwater contamination associated with disease outbreaks. In Nigeria, Adetunji and Odetown (2011) observed that water samples collected from an area characterized by high-density septic tanks were found to be contaminated with coliforms and other bacteria.

1.2 Statement of the Problem

It is estimated that the average person in developed countries uses 200–800 litres per day, compared to 60–150 litres per day in developing nations (Fogden, 2009). Getting potable water has received full international recognition over the past few years due to its impact on economic development and human health. However, in most countries in Sub-saharan Africa, a large proportion of the population depends on unimproved sources of drinking water (Monney, 2013). Again, in Sub-Saharan Africa, access to piped water supplies has decreased in urban areas and one-fifth of people in rural areas still rely on surface water (WHO & UNICEF, 2011). According to Penrose *et al.*, (2010) cholera incidence is most closely associated with informal housing, population density and the income level of informal settlements. Denu township is no exception to the above problem. In such settlements, the majority of the people rely on unimproved water. The density and proximity of these sanitary facilities to unimproved water may lead to groundwater pollution dependent on the geology. According to Ghana Statistical Service (GSS) (2014), the area is underlain by Pre-Cambrian rocks of the Birimean formation and contains most of the mineral deposits, especially sand, stone and other minerals. The rock enables water movement and yielding boreholes. Such boreholes may provide the much-needed water for the informal settlements of Denu township. Informal settlements form a major part of Denu township and their expansion is based on employment opportunities created by the plantations and the education found in the area. The informal settlements lack proper sewage disposal systems to accommodate a large number of people. This makes a citizen of the community resort to all kinds of water for daily activities and this affects the health of residents in the community. It is against this background and other observations in the community that this study seeks to assess household water quality and sanitation systems at Denu in Ketu South municipality.

1.3 Research Objective

The research is to determine the household water quality & sanitation systems at Denu in Ketu South municipality. The specific objectives of this research were to determine;

1. The sources of drinking water at Denu.
2. Types and usage of sanitation systems
3. Pipe water supply disparities
4. To find out the factors influencing the site and distance of sanitation facilities
5. To determine the levels water quality parameters in household water sources

1.4 Research Questions

The study was guided by the following questions

1. What are the sources of drinking water at Denu?
2. What are the levels of microbes in drinking water?
3. Is sanitation issues around water bodies are contributing factors to the safety of drinking water**?**

1.5 Significance of the Study

Undertaking this study will provide key information for taking appropriate action to improve potable water in the Denu in the Ketu South Municipality. This study will also provide information on the judicious use of water in the study area and propose measures for proper treatment and management of water. It will also in the long run reduce the incidence of diarrhoea, as well as deaths caused by ingesting water contaminated with Escherichia coli. This research will also give us the avenue to communicate to the water supply companies to improve on their services that have enough routine monitoring of their pipelines and also locate their pipelines at where the environment is clean and devoid of potential pathogenic contamination. The study provides opportunities for future studies to fill in the gaps that this study could not address. The study adds to the existing body of knowledge on the topic under study and plays a vital role in providing people with information on public health. Finally, this study highlighted the problem of attaining safe water and good sanitation, and then developed and made a recommendation to policy and decision-makers on how best the water supply can be improved.

1.6 Limitations of the Study

A general study would have been good to make better inference however the study was concentrated to Denu township in the Ketu South Municipality. Time and money was also a limiting factor to the study in a way that not all water resources was taken but limited to some selected water sources within the municipality.

1.7 Organization of the study

Chapter one introduces the study and provides the outline of the study which is to investigate the household water quality & sanitation systems at Denu in Ketu South municipality. It also captures the background information, problem statement, objective of the study, research questions, significance of the study, and limitations. Chapter two deals with the review of literature related to the subject of study. The review involves in-depth studies related to the problem under study. The third chapter describes the methodology used in the study. Specifically, the research design, the research instrument, sample and sampling technique, the procedures for data collection and the data analysis are discussed. The analysis, results and discussion are presented in chapters four. This chapter captures the interpretation of all the interview responses and content analysis of the data collected on the field of study. In chapter five, the main focus is the summary, conclusions and recommendations. This chapter provides a summary of all the chapters in the study. In addition, the chapter also made few recommendations on alternative development approach before drawing a conclusion on the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Global Water Supply Disparities

In 2010 more than 780 million people worldwide lacked access to improved drinking water (WHO & UNICEF, 2012). The WHO defines "improved" drinking water sources as any sources that are "by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter. Through their "Water Ladder" framework, the WHO/UNICEF lists a piped water connection, either in the home or a public area at the top of the ladder in terms of an improved water source. The proportion of the population that uses improved drinking water sources varies significantly by country and region (WHO & UNICEF, 2011).

Of the estimated 884 million people without access to improved sources of drinking water in 2008, 37% live in Sub-Saharan Africa, 25% in Southern Asia, 17% in Eastern Asia and 9% in South-Eastern Asia. Use of piped water on premises is lowest in Sub-Saharan Africa, Southern Asia and South-Eastern Asia. Of particular concern among those people without access to improved drinking water sources are those who rely on surface water sources. Such sources include rivers, dams, lakes, ponds and canals, and are often the most susceptible to pollution and most likely to have poor water quality. Since 1990, use of surface water sources has decreased significantly and accounts for only a small proportion of drinking water sources in most regions. For example, only 2% of the rural population in Southern Asia and 5% of the rural population in South-Eastern Asia use surface water sources (WHO & UNICEF, 2011).

In contrast, in Sub-Saharan Africa, 20% of rural dwellers still rely on surface water sources. It is clear that Sub-Saharan Africa is not on track to meet the target; in 2008 40% of the total population still lacked access to improved drinking water sources, as compared to 51% in 1990. However, the population growth in Africa, which is the highest of all regions, outstripped the number of people gaining access. According to the estimates of the UN Population Division, the population in Sub-Saharan Africa grew by 304 million people over the period 1990-2008, while only 237 million gained access to improved drinking water and as a result, the population using unimproved drinking water sources increased by 27 million in urban areas and 39 million in rural areas. Of the 48 countries that are classified as least developed countries (LDCs), 32 are in Sub-Saharan Africa. Globally, only 42% of official development assistance for drinking water and sanitation is targeted to low-income countries. This is reflected in the limited progress in accelerating access to safe drinking water made by LDCs and other low-income countries (OLICs) since 1990 (WHO, 2010). LDCs have seen an increase of only 7 percentage points (from 54% to 61%) in the use of improved drinking water sources and OLICs have seen an increase of 11 percentage points (from 68% to 79%). Meanwhile, lower-middle-income countries (LMICs) saw an increase of 16 percentage points (from 72% to 88%) and upper-middle-income countries (UMICs) saw an increase of 8 percentage points (from 88% to 96%) (WHO & UNICEF, 2011).

2.2 Overview of Ghana's Water Resources

Ghana's water resources are divided into surface and groundwater sources. Surface water resources are mainly from three river systems that drain Ghana, namely: the Volta, South Western and Coastal river systems. The Volta system is made up of the Red, Black and White Volta Rivers as well as the Oti River (Ministry of Water Resources Works and Housing, 2010). The southwestern river system is made up of the Bia Tano, Ankobra and Pra rivers. The Tordzie/Aka, Densu, Ayensu, Ochi-Nakwa and Ochi-Amissah comprise the coastal river systems. These river systems make up 70%, 22% and 8% respectively of Ghana"s total land area of about 240,000 km2. In addition to these, the only significant natural freshwater lake in Ghana is Lake Bosomtwi with a surface area of $50km^2$, and a maximum depth of 78m. In terms of groundwater resources, Ghana is underlain by three main geological formations, namely the basement complex comprising crystalline igneous and metamorphic rocks; the consolidated sedimentary formations underlying the Volta basin (including the limestone horizon) and the mesozoic and cenozoic sedimentary rocks. These formations represent 54%, 45% and 1 % of the land area of the country respectively (Ministry of Water Resources Works and Housing, 2010).

2.2.1 Water Availability

The total annual runoff is 56.4 billion m3 with the Volta River accounting for 41.6 billion m3. The mean annual runoff from Ghana alone is about 40 billion m3. The Volta, Southwestern and Coastal systems contribute 65%, 29% and 6%, respectively, of this runoff. However, the runoffs are characterized by wide disparities between the wet season and dry season flows. The total amount of groundwater available in the country is yet to be determined (Ministry of Water Resources Works and Housing, 2010). The depth of aquifers in the basement complex and the Volta Basin is normally between 10m to 60m with yields rarely exceeding 6m3/h. The aquifer depths in the mesozoic and cenozoic formations are usually between six and 120m with average yields of about 184m3/h, particularly in the limestone aquifer. Groundwater occurrences in limestone formations, which also exist, are located much deeper, typically in the range of 120m to 300m. The average yield in the limestone formation is 180m3/h. Experience has shown that groundwater has several advantages over surface water for the provision of water supply and is used as the first choice among other options for community water supplies whenever it is available (Ministry of Water Resources Works and Housing, 2010).

2.2.2 Water Demand

The main consumptive uses of water in Ghana are drinking water supply, irrigation, livestock watering, and industrial supply. Based on surface water resources alone, the consumptive water demand for 2010 was estimated at 3.0 billion m3, which is equivalent to about 7.4% of the annual runoff from Ghana alone. The main non-consumptive uses are inland fisheries, water transport, and hydropower generation. The projected demand for hydropower generation in 2010 was 37.8 billion m3, which could also be met from the total surface water resources available (Ministry of Water Resources Works and Housing, 2010).

2.2.3 State of Water Quality

The quality of water resources, which hitherto was fairly good, has in very recent years been showing signs of gradual deterioration. Water pollution of varying degrees is prevalent in almost all the river basins of Ghana but is more pronounced in urbanized river basins like the Densu and in areas where mining activities take place especially, in the Pra, Ankobra, and Birim basins

(Ministry of Water Resources Works and Housing, 2010). In the rainy season, because of high river flows, the colour of waters, the total dissolved or suspended solids and conductivity change or increase considerably. For instance, a Total Dissolved Solids (TDS) value of over 2000mg/l has been found in the Subin River whilst a suspended solid load of 5,067 kg/day has been recorded for the Birim River. Dumping of domestic, industrial and agricultural wastes into rivers and streams, particular the South–Western and Coastal river systems have resulted in high levels of pollution in the surface water that requires attention. Problems associated with the quality of groundwater are generally localized. For instance, the problem of high fluoride concentrations in groundwater caused by natural geologic conditions and the decomposition of plant material near industrial sources occurs mostly in the White Volta Basin especially in the Bongo District of the Upper East Region. Concentrations of 1.5 to 5.0mg/l have been found in boreholes in the Bongo granitic formation and a concentration of 6.0mg/l found at Lungo as against the WHO guideline value of 1.5mg/l (Ministry of Water Resources Works and Housing, 2010).

The problem of high iron concentrations in groundwater is more widespread and prevalent in the Ankobra, Pra, Tano, Ayensu, Main Volta and Lower Volta River basins. Ground water in these areas has unacceptable iron concentrations by WHO standards. Areas around Ave Dakpa, Peki, Winneba, Wassa Simpa and Prestea have exceptionally too much iron concentration in their groundwater resources and care must be taken in resorting to groundwater for drinking purposes in such areas. Seawater intrusion and high salinity of groundwater has been found to be prevalent in the coastal areas particularly in the Pra, Ankobra, Ayensu Ochi-Nakwa and Lower Volta River basins. High salinity of groundwater has also been found to occur in the Densu, Ayensu, Ochi-Nakwa, Kakum/Bruku, White Volta and Lower Volta River basins (Ministry of Water Resources Works and Housing, 2010).

2.3 Drinking Water in Ghana

An improved source includes a public standpipe or outdoor tap, a protected well, a protected spring, or rainwater. However, these sources don't completely prevent water-borne diseases. Children have high mortality rates and serious health issues due to the lack of safe water access (Kristine Cheng, 2013), Microbial and/or chemical contaminants can infiltrate into piped distribution systems, especially where water is supplied intermittently, such as in Ghana. The low water pressure, creating an intermittent distribution system, will allow the ingress of contaminated water into the system through breaks, cracks, joints and pinholes (WHO, 2012). The situation is highly likely to occur in Ghana due to its aged piping network. Water flowing out of the tap is potentially contaminated and requires additional treatment for drinking.

2.3.1 Sources of Water for Drinking Purposes in Denu

There are a lot of water resources such as streams, rivers, lakes, dams, waterfalls, underground and rainwater in Ghana (Wiafe, 2014). However, Ghana's water resources have been under increasing threat of pollution in recent years. This threat can be attributed to improper planning of human settlements and anthropogenic activities such as farming very close to water bodies (Theresa, 2012). These activities are very common in rural and peri-urban areas. Water, the source of life and human civilization has become one of the major issues of the 21st century. It is probably the most valuable natural resources available to man, without which nothing can survive. Unfortunately, in many areas of the world, it is not possible to obtain a ready source of pure drinking water. In addition to this, no other public health issue affects a large proportion of the population than that of drinking water. Thus, through the ages, the contamination of drinking water by both point (e.g. sewage disposal) and non-point (runoff from agricultural farms) sources of pollution have resulted in several catastrophes and human death. Thus, currently, water pollution has become a major subject of public concern the world over. Denu in the Volta – Region of Ghana is no exception. The nature of the area has made it such that the indigenous population uses surface waters such as rivers, streams, ponds and springs as their only source of potable water. The qualities of these water bodies vary naturally and widely, depending on climate, season, and the geology of the local bedrock. Uncontrolled domestic wastewater discharge into streams has resulted in eutrophication of streams as evidenced by substantial algal bloom and dissolve oxygen depletion in the subsurface water. This has led to a large fish kill and another oxygen requiring organism (Pandey, 2003).

2.4 Drinking Water and How it is Affected by Environmental Conditions

Drinking water, also known as potable water, is water that is safe to drink or to use for food preparation (WHO/UNICEF, 2004). The amount of drinking water required varies. It depends on physical activity, age, health issues, and environmental conditions Americans, on average, drink one litre of water a day and 95% drink less than three litres per day. For those who work in a hot climate, up to 16 litres a day may be required. Water is essential for life, (Rebecca *et al.*, 2013). Typically, in developed countries, tap water meets drinking water quality standards, even though only a small proportion is consumed or used in food preparation. Other typical uses include washing, toilets, and irrigation. Gray water may also be used for toilets or irrigation. Its use for irrigation however may be associated with risks. Water may also be unacceptable due to levels of toxins or suspended solids (WHO, 2010).

2.5 Household Water Storage, Microbial Quality and Infectious Disease Risks

Key factors in the provision of safe household water include the conditions and practices of water collection and storage and the choice of water collection and storage containers or vessels. Numerous studies have documented inadequate storage conditions and vulnerable water storage containers as factors contributing to increased microbial contamination and decreased microbial quality compared to either source waters or water stored in improved vessels (Dunne, 2001). Some studies also have documented increased risks of waterborne infectious diseases from the inadequately stored water compared to water stored in an improved vessel (safe storage), treated in the home to improve microbial quality, or consumed from a quality source without storage. Higher levels of microbial contamination and decreased microbial quality are associated with storage vessels having wide openings (e.g., buckets and pots), vulnerability to the introduction of hands, cups and dippers that can carry faecal contamination, and lack of a narrow opening for dispensing water. Some studies have noted the vulnerability of storage vessels with these undesirable characteristics to faecal and other contamination without having reported microbiological data on water quality or increased levels of diarrheal disease (Miller, 1984). Other factors contributing to greater risks of microbial contamination of stored water are higher temperatures, increased storage times, higher levels of airborne particulates (dust storms), inadequate handwashing and the use of stored water to prepare weanling and other foods that also become microbiologically contaminated and contribute to increased infectious disease risks (Dunne, 2001).

2.6 Health Implications Associated with Drinking Unsafe Water

The safety and accessibility of drinking-water are major concerns throughout the world. Health risks may arise from the consumption of water contaminated with infectious agents, toxic chemicals, and radiological hazards. Improving access to safe drinking-water can result in tangible improvements to health. Providing access to safe water is one of the most effective instruments in promoting health and reducing poverty. Safe drinking water is treated water that has been tested for harmful and potentially harmful substances and has met or exceeded drinking water quality standards (Anniston Water Works and Sewer Board, 2017). In 2015, 71% of the global population (5.2 billion people) used a safely managed drinking-water service – that is, one located on-premises, available when needed, and free from contamination (WHO, 2017). Shortage or lack of safe water leads to sanitation problems and water-borne diseases, including diarrhoea, cholera, dysentery, etc. because end-users resort to use polluted surface water in open wells, rivers and dams (Graciana, 2010). Even though the untreated surface water may not be harmful if used for bathing, cleaning and washing, it can have adverse health effects on drinking or cooking (Gine & Perez, 2008).

Water quality on the other hand refers to chemical, physical, biological and radiological characteristics of water (Nancy, 2009). It is a measure of conditions of water relative to the requirement of one or more biotic species and or to any human need or purpose (Johnson et al, 1997). The water quality of rivers and lakes changes with the seasons and geographic areas, even when there is no pollution present. There is no single measure that constitutes good water quality. For instance, water suitable for drinking can be used for irrigation, but the water used for irrigation may not meet drinking water guidelines.

2.7 Testing Microbial Quality of Drinking Water

Testing drinking water for biological, pathogenic, diseases and Public health quality are essential in providing information about disease risk and when disinfection methods are needed to protect public health. What, though, is the optimal frequency of such testing for the protection of public health? The general importance of water quality and testing is to ensure good water quality has long been established (Naval Institute, 1990). In the 1880s, typhoid fever, cholera, and bacterial dysentery (Shigella spp.) were discovered to be caused by bacteria entering the water from faecal contamination, which lead to a general recognition of the importance of water testing to public health. Because testing directly for all pathogens is impractical, microbiologists sought a universal microbial indicator of fecal pollution and identified *Escherichia coli* (E. coli) as the best indicator (Water Aid, 2000.)

Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with disease vectors, pathogens or unacceptable levels of toxins or suspended solids. Endemic and epidemic disease derived from unsafe water drinking affects all nations (CDC, 2010). Outbreaks of the waterborne disease continue to occur in both developed and developing countries, leading to loss of life, disease and economic burden for individuals and communities (CDC, 2010). In addition to microbial risks to drinking-water, safety may also be compromised by chemical and radiological constituents. In general terms, the greatest microbial risks are associated with ingesting water that is contaminated with human or animal faeces. (CDC, 2006). Water safety has been credited for adding 25 years to the average life expectancy in the USA over the last 100 years. Medical advances have only added 5 years. Part of that safety is simply the disinfection of water being delivered to consumers, one that has become so commonplace we do not think about what could happen or might have happened had the utilities not been vigilant (Adebusuyi, 1985) Filters, disinfectants, flushing programs, deposit control in pipes, are all part of that effort. However, utilities are tasked to remain vigilant in their treatment because unknown and uncontrollable events can create changes that, often with little warning. Assuming water coming into your home or facility has enough residual disinfectant to adequately protect you when it arrives is not a guarantee. Water systems degrade and operational changes get made (Adebusuyi, 1985)

2.8 Physical and Chemical Properties that Affect the Safety of Drinking Water

Physical contaminants primarily impact the physical appearance or other physical properties of water. Examples of physical contaminants are sediment or organic material suspended in the water of lakes, rivers and streams from soil erosion (APEC, 2017). Chemical parameters tend to pose more of a chronic health risk through a buildup of heavy metals although some components like nitrates/nitrites and arsenic can have a more immediate impact. Physical parameters affect the aesthetics and taste of the drinking water and may complicate the removal of microbial pathogens (US EPA, 2015) Water pollutants that occur in the various water bodies include physical, chemical and biological inputs. Many of the chemical pollutants found in the water are very toxic to human and aquatic life. The physical and chemical properties of the water including colour, temperature, acidity, conductivity and eutrophication are easily altered in water bodies. (Hesterberg, 1998)

2.9 Difference between Water Safety and Water Quality

Water safety and quality are fundamental to human development and well-being. Providing access to safe water is one of the most effective instruments in promoting health and reducing poverty (Pandey, 2003).

2.9.1 Water Safety

It is the procedures, precautions and policies associated with safety in, on and around bodies of water, where there is a risk of injury or drowning. Safe water also goes to the point of checking how purity a source of water is. The waterborne disease remains one of the major health concerns in the world. Diarrhoea diseases, which are largely derived from contaminated water and inadequate sanitation, account for 2.4 million deaths each year and contribute over 73 million (WHO 1999).

2.9.2 Water Quality

It is also described as the condition of the water, including physical, chemical and biological characteristics, usually concerning its suitability for a particular purpose such as drinking or swimming. Water quality is measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), or the amount of material suspended in the water (turbidity). In some bodies of water, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality (WHO 1999).

2.10 Mapping Water Safety Plans

A Water Safety Plan (WSP) is an approach for consistently ensuring the safety of drinking-water supply through the use of comprehensive risk management procedures that encompass all stages of water supply from the catchment to the consumer (WHO, 2004). This holistic, systematic, and integrated approach is used to identify and prioritize potential risks to a specific water supply chain and implement best practices to mitigate those threats (CDC, 2009). The aim of a WSP is "To consistently ensure the safety and acceptability of a drinking water supply" (Barttram et al 2009). The primary objectives of a WSP are to: prevent or minimize contamination of source waters; reduce or remove contamination through treatment processes; and prevent contamination during storage, distribution, and handling of drinking water (WHO, 2011).

While WSPs can vary in complexity and their use can encompass all water supply systems ranging from self-supply systems to fully-fledged water utility supply systems, its application will be looked at within the context of water utilities. WSPs are a vital component of the WHO's framework for safe drinking water. WSPs has to have three main elements: system assessment, monitoring, and management and communication plans. These elements are steered by health-based targets and overseen through the surveillance of the drinking-water supply. System assessment is used to determine the capacity of the whole water supply chain to deliver water that meets the identified targets and to also assess the design criteria for new systems (Davison et al, 2005).

During monitoring, measures that will collectively control determined risks and ensure achievement of health-based targets are identified. The identified monitoring mechanisms ensure the timely detection of any performance deviation. Management and communication plans are used to describe the actions to be taken in both normal and incident conditions. This process also includes documenting system assessment including upgrade and improvement planning, monitoring and communication plans and supporting programmes (Davison et al, 2005). The WSP process has been broken down into several steps for ease of implementation. For example, Bartram et al (2009) suggest an eleven step WSP implementation process. The first step is assembling of the WSP team which involves the engagement of senior management team and securing of financial support. After the completion of steps, two to nine, periodic reviews of the WSP is carried out to keep the plan up to date. Step eleven entails reviewing the WSP following the occurrence of an incident, emergency or near miss. Despite requiring certain minimum standards in terms of the above steps, the GDWQ emphasises the need for flexibility indicating that the process "should rely on the water supplier's existing practices and fit the way that a supplier is organized" (WHO, 2011).

The process should not be seen as an alternative to already existing programmes but rather as a supportive mechanism aimed at enhancing these programmes. While it may not be possible to fully establish a WSP all at once, undertaking steps such as system mapping, hazard identification, and risks assessment "will provide a framework for prioritizing actions and will identify the requirements for continuous improvement as resources become available" (WHO, 2011). In essence, the process should initially be geared towards ensuring the optimal functioning of the existing system. In cases where the water supplier does not manage the catchment, WSPs play an important role in identifying existing and potential hazards and risks. While remediation of some hazards, such as those in the catchment, may take time, this should not be a reason to delay the start and implementation of the WSP process (WHO, 2011). Utilities might face several practical challenges in the initiation, development and implementation of a WSP. Some of the challenges identified by the WHO (2011) include:

1. mistaken perceptions that one prescribed methodology must be followed;
2. that WSP steps must be undertaken with risks managed from source to tap in a defined order;
3. that developing a WSP always requires external expertise;
4. that WSPs supersede, rather than build on, existing good practices; and
5. those WSPs are necessarily complicated and are not appropriate for small supplies.

Notwithstanding these challenges, the implementation of WSPs can be of various benefits to water suppliers; this approach is flexible and serves to (CDC, 2012):

1. identify opportunities for low-cost improvements to operations and management practices that can enhance water safety;
2. improve efficiency and reduce expenses;

3. improve stakeholders' understanding of the complete water supply chain and its vulnerabilities;

4. improve communication and collaboration between key stakeholder groups, such as water providers, consumers, regulatory authorities and commercial, environmental and health sectors; and

5. help substantiate and prioritize capital improvement needs and help leverage financial support. In addition to the above benefits, the implementation of WSPs also improves compliance, shows 'due diligence' and can lead to a quicker response to incidents and improvement of existing staff knowledge (WHO, 2011). Compared to the previous reactive and retrospective water testing and disease surveillance systems, WSPs are considered to be a reliable preventative risk management approach in protecting public health (Byleveld *et al.*, 2008).

2.11 Mapping Water Safety Plans in Developing Countries

The implementation of WSPs in developing countries is mostly at the pilot or introductory stages. Godfrey and Howard (2004) indicate "crisis management", the norm in many water utilities in developing countries is one of the main reasons for the lack of wide application of WSPs despite its assurance for better water quality and support for more effective asset management. However, as an understanding of WSPs continues to increase, many developing countries are adopting this approach. For example, in addition to the three WSPs studied for this research (Hyderabad, Kampala, and Spanish Town) several other countries have implemented WSPs. Other than WHO, several other international organizations are involved in the promotion of WSPs. One such example is the IWA which through its 'Bonn Charter for

Safe Drinking Water' (IWA, 2004) promotes the use of WSPs in achieving the goal of "*good safe drinking water that has the trust of consumers*". Other key players in the promotion of WSPs include USEPA, CDC, and university institutions. Through the efforts of these organizations and local initiatives by governments and water utilities, WSPs are being implemented in almost all regions of the world. Some countries such as Iceland have gone a step further and have legislated the use of WSPs while others intend to do so.

Godfrey and Howard (2004) identify several aspects which influence the development and implementation of WSPs in developing countries:

1. "Limited data availability – Many systems in the developing world are only recently developing the culture of data collection and storage";
2. "Unplanned development – Limited regulation has resulted in unplanned development making it difficult to locate all supply mains";
3. "Sanitation – Poor access to urban sanitation mean potential cross contamination of water pipes is common";
4. "System knowledge – Much of the information on the piped networks may not be available as records may have been removed by contractors, colonial powers" and
5. "Equipment/human resource availability - Selection of appropriate water quality parameters should consider availability of resources".

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

The survey conducted in the Ketu South Municipality. The Ketu South Municipality lies within latitudes 6° 10' 0" north and 6 ° 00' 0" north, and longitude 1 ° 00' 0" east and 1 ° 11' 0" west. It shares a border with the Republic of Togo on the east, the Keta Municipality on the west, the north with Ketu North District and the Gulf of Guinea to the south (Figure 1).

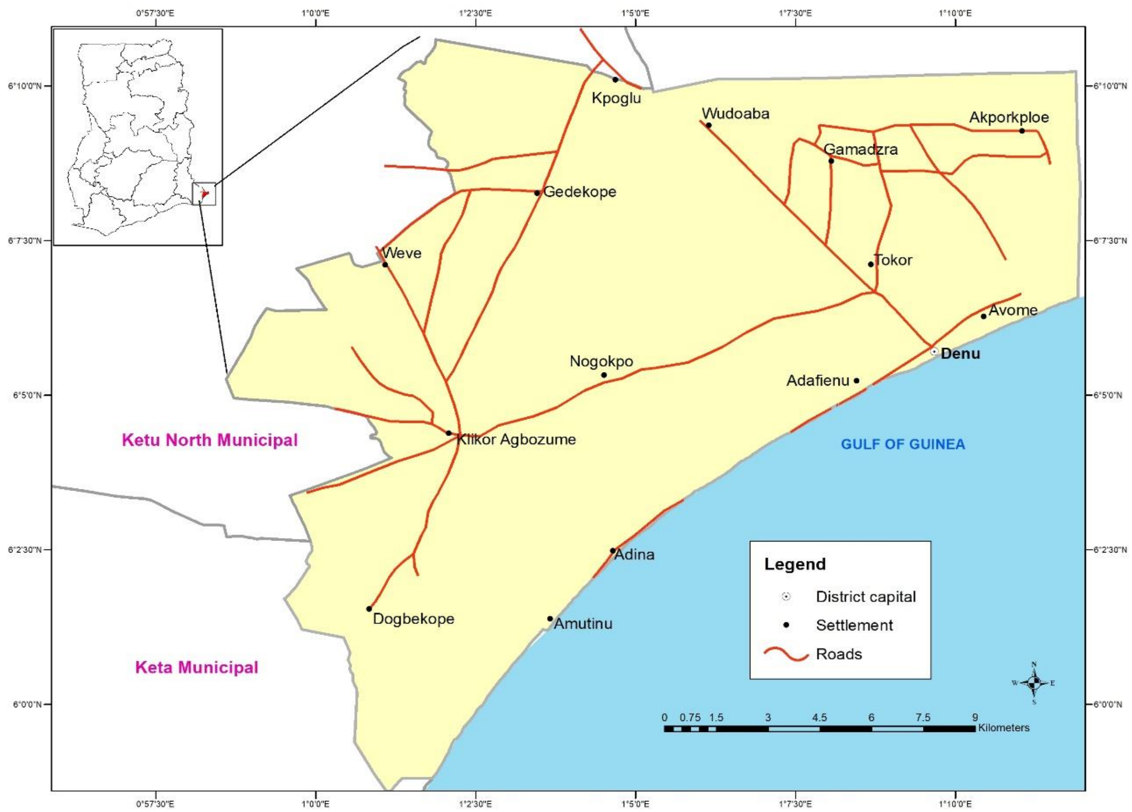

Figure 1:Ketu South Municipality (GSS, 2014)

Source: Field Survey (2020)

The Municipality has a land area of approximately 779 square kilometres. Denu in the Ketu South Municipality of Ghana. Denu is located along Accra-Aflao road. It is about 2km from Aflao. The main language spoken is Ewe. The town has a market which takes place every four days. The main occupations are fishing, vegetable crop production and trading (Ghana Statistical Service, 2014).

3.1.1 Climate in Ketu South and How it Affects Water Safety in the Municipality

The Municipality has an average annual rainfall of 1,270mm and two rainy seasons. The major rainy season starts in March and ends in August whiles the minor is between September and November. The remaining months spans the harmattan dry season. This means that the quality of surface water will be affected adversely when it is supposed to be used for drinking purposes (Ghana Statistical Service, 2014).

3.1.2 Waste Disposal and its Effect on Water Quality.

The most common method of solid waste disposal is a public dump (open space) (50.7%), public dump (container) (26.9%) and only 2.8 per cent collected. Dumping of solid waste indiscriminately is practised by 9.6 per cent of the households. For liquid waste disposal, throwing waste onto the compound (37.8%), thrown onto the street or outside (31%) and thrown into the gutter (16.6%) are the most common practices by households in the district. (Ghana Statistical Service, 2014)

3.1.3 Vegetation and its Effect on Water Safety

The Ketu South Municipality lies within the coastal scrub. It has no forest reserve. Surface water bodies are likely to be polluted easily considering the type of human activities that go on in the municipality.

3.1.4Location and Sources of Water Bodies in the Municipality

The main source of drinking water for the inhabitants of Ketu south municipality is a borehole, hand dag well, GWCL and in some cases, surface water bodies.

3.2 Study Design

Descriptive cross-sectional survey research design will be adopted for this study, particularly the case study survey design.

3.2.1 Sample Population and sample size

The population for the study will be residents identified in Ketu south municipality. A sample size of 58 respondents was used for the study.

3.2.2 Sampling Technique

Data will be collected using both Primary and Secondary data collection technique. Simple random sampling technique will be used to select the participants. Simple random sampling will be used to select mine workers. Consent of the respondents will be obtained by presenting a letter from the university of to the respondents involved

3.2.3 Primary Data Collection

Primary data will be collected by the usage of questionnaire, personal observation and focus group discussion and a laboratory test analysis for mercury and arsenic. The purpose of the study will be explained to the respondents before engaging them for data.

3.2.4 Secondary Data Collection

Secondary data will be obtained from books, Journals, News Papers, published documents as well as internet sources. Secondary source of data will therefore be used to enrich the study with literature and knowledge based on theories, making critiques and ease to analysis of the collected data.

3.3 Sampling of Water for Microbial Testing

3.3.1 Sampling Sites

Samples of water from a borehole, hand dag well, GWCL and surface water bodies in Denu township were taken. The sampling sites were selected purposively concerning accessibility and where citizens in the district fetch water. The sampling was done monthly for one-month consecutive months.

Table 1:Sampled Points and GPS Locations

Sampling Point	Water Sources	GPS Address
1.Zongo chief palace	Hand dug wells	VZ- 0005-7648
2. Denu Afekotuime	Water Supply Station	VZ - 0002-9343
3.Denu chif palace	Hand dug well	VZ-0003-9357
4 Health Insurance Directorate	Mechanized Bole Hole	Vz- 0007-9407
5. Laklivikope	Bore Hole	VZ -0167-9207
6. Akame	Bore Hole	VZ-0423-8651
7. Akame	Hand Dug well	VZ-0423-5733
8. Honolulu Guest house	Standpipe	VZ-0065-7255
9. Hatsukope	Standpipe	VZ-0089-5741
10. Hatsukope	Hand dug well	VZ-0089-5848
11. Hatsukope Kpota	Hand dug well	VZ-0089-1200
12. Hatsukope Basic school.	Bore Hole	VZ-0089- 8917
13.Denu Avedzi	Hand dug well	VZ-0000-8299

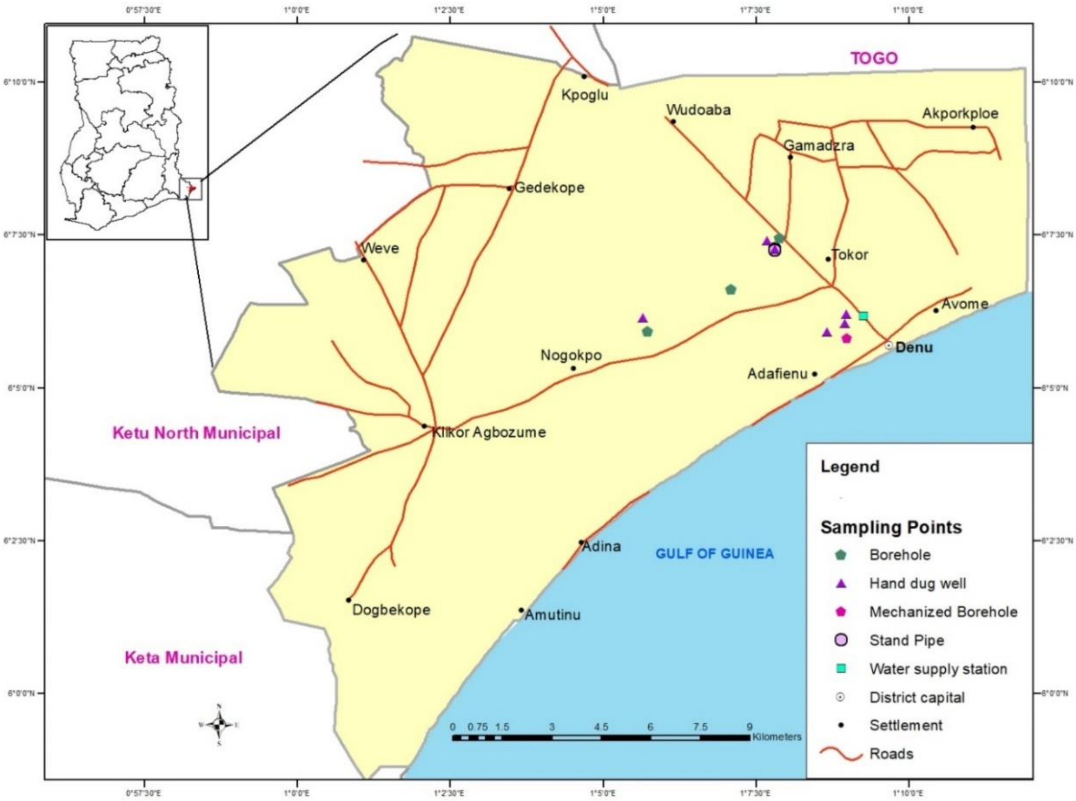

Figure 2:Ketu-South Municipality Showing Sampling Location of Water Sources

3.3.2 Water Sampling

Monthly water samples were collected from the borehole, hand dag well, GWCL and surface water bodies in duplicate amounting to eight water samples. Plastic sample bottles of 1.5 L were washed with non-ionic detergent and well rinsed with tap water. Before sampling, the bottles were rinsed three times with sample water before being filled with the water. Sample bottles were submerged to a depth of 20-30 cm opened, filled, corked and removed. Samples collected were immediately placed in an ‘ice chest’ in ice packs and transported to the laboratory where analyses were performed within six hours.

3.3.3 Total Coliform Bacteria

Standard plate count method was used (American Public Health Association, American Water Works Association, Water Environment Federation, 1999). Petri dishes, Pasteur pipette and other equipment were sterilized using an autoclave. One hundred millilitres of the water sample was taken into a sterilized Petri dish. Ten millilitres of sterilized Maconkey Agar (culture media) was added. The Petri dish was swirled to mix evenly. The sample was allowed to stand and resuscitate for 30 minutes. The Petri dish was inverted in an incubator at 44 ^{o}C for 24 hours. The number of bacteria formed was counted in Coliform Units (CFU).

3.3.4 Enumeration of Escherichia Coli

Standard plate count method was used (American Public Health Association, American Water Works Association, Water Environment Federation, 1999). Petri dishes, Pasteur pipette and other pieces of equipment were sterilized using an autoclave. One hundred millilitres of the water sample was taken into a sterilized Petri dish. Ten millilitres of sterilized Maconkey Agar (culture media) was added. The Petri dish was swirled to mix evenly. The sample was allowed to stand and resuscitate for 30 minutes. The Petri dish was inverted in an incubator at 37 ^{o}C for 24 hours. The number of Escherichia Coli formed was counted in Coliform Units (CFU).

3.3.5. Salmonella

Membrane filter technique using Chromocult Coliform Agar Chromocult Coliform Agar determines the presence or absence of coliform bacteria and *E. coli, and salmonella* in water. A water sample is passed through the membrane that retains the bacteria. Following filtration, the membrane containing bacterial cells is placed on the media and incubated at 36 ± 1°C for 24 ± 1 h. In contrast, dark-blue to violet colonies are recorded as *E. coli*. In this method, an appropriate volume (1mL) of the wastewater sample was added to a known volume of dilution water (99mL). Three serial dilutions with 99mL dilution of dilution water and 1mL of the resulting solutions were performed and the final solution was filtered through a sterile micropore filter by suction, thereby capturing any coliforms. With the aid of sterile forceps, the filter membrane was placed aseptically and rolled onto the Chromocult Coliform Agar in a Petri dish. The dish was inverted, closed and incubated at 35°C. After 24 hours of incubation, the number of Salmon to red colonies is recorded as coliforms by visual examination whiles dark-blue to violet colonies are recorded as *E. coli*. And green to turquoise colonies are counted as salmonella. American Public Health Association, American Water Works Association, Water Environment Federation, (1999).

3.4 Data analysis

Data will be entered into Microsoft Excel (Microsoft, 2010) and then transferred to SPSS 22 for analysis. Descriptive statistics will be calculated by demographic and other factors. Levels of water samples will be analysed and One-way ANOVA will be developed.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Bio Data of Respondents

Table 2:Bio data of Respondents

Parameter	Frequency	Percentage
Gender		
Male	27	47%
Female	31	53%
Breadwinner		
Grandmother	2	3%
Myself	3	6%
Father	41	71%
Mother	12	21%
Educational		
Secondary/technical/vocational	11	19%
Primary	13	22%
Tertiary	21	36%
No education	13	22%
Main job		
No employment	1	2%
Self-employed/entrepreneur	50	86%
Formal employee	6	10%
Non-contract employment/daily labour employment	1	2%
Resident status		
Landlord/landlady	50	86%
Tenant	8	14%

Source: Field Survey (2020)

The demographic characteristics of the respondents from the analysed data are discussed below. This includes the sex/gender, breadwinner, educational status, main job and resident status. The Table 2 revealed that majority of the respondents were females of 31(53%) and males 27(47%). The percentages of sex/gender of the respondents were little above the female and below the male percentages in the 2010 population census where the female population in the Municipality is 51.6 per cent while the males constitute 48.4 per cent (GSS, 2014). From the table majority of the respondents who were breadwinners were mostly fathers 41(71%), mothers of 12(21%), and others. Of the educational status, most of the respondents had received tertiary education of 21(36%), Educational level in the community was high as majority of the respondents have attained some level of literacy and this was in line with the 2010 population census (GSS, 2014) Most of the respondents were self-employed/entrepreneurs of 50(86%), formal employee of 6 (10%), non-contracted/daily labour employment of 1(2%) and no employment of 1(2%). Majority of them were landlords/landladies of 50(86%) and tenant of 8(14%). This means that majority of the respondents do look after the houses they live and as such responsible for every sanitation activity that go on in the house.

4.2 Water Sources, Location and Treatment

A large proportion of the World's people do not have access to improved or microbiologically safe sources of water for drinking and other essential (WHO, 2002). From the figure below the main water sources of the respondents was hand-dug/open well representing 91% and the least water sources was borehole/well with a hand pump of 9%. A household is considered to have access to an improved water source if it gets good drinking water (UNICEF & WHO, 2008). UNICEF and WHO (2008) stated that water sources such as pipe borne from water supply system, a public standpipe, borehole and dug well with pump, a protected spring, a well-developed rainwater harvesting system, a reliable water vendor or water tank truck are good drinking water sources. The location of the main sources of water; 88% were within the compound, 9% were outside the compound/yard and 3% were at the backyard. According to Odai and Dugbantey (2003), in Ghana, there is no law governing the arrangement of on-site sanitation and groundwater tapping points in a private compound. For the reasons for the location of the main sources of water; 66% just decide to site anywhere while 34% were constructed by contractors. Respondents who share their water source with others (Yes) were 93% while 7% do not share their water with others (No). For the treatment of water, 69% of the respondents do not treat their water while 31% treat their water.

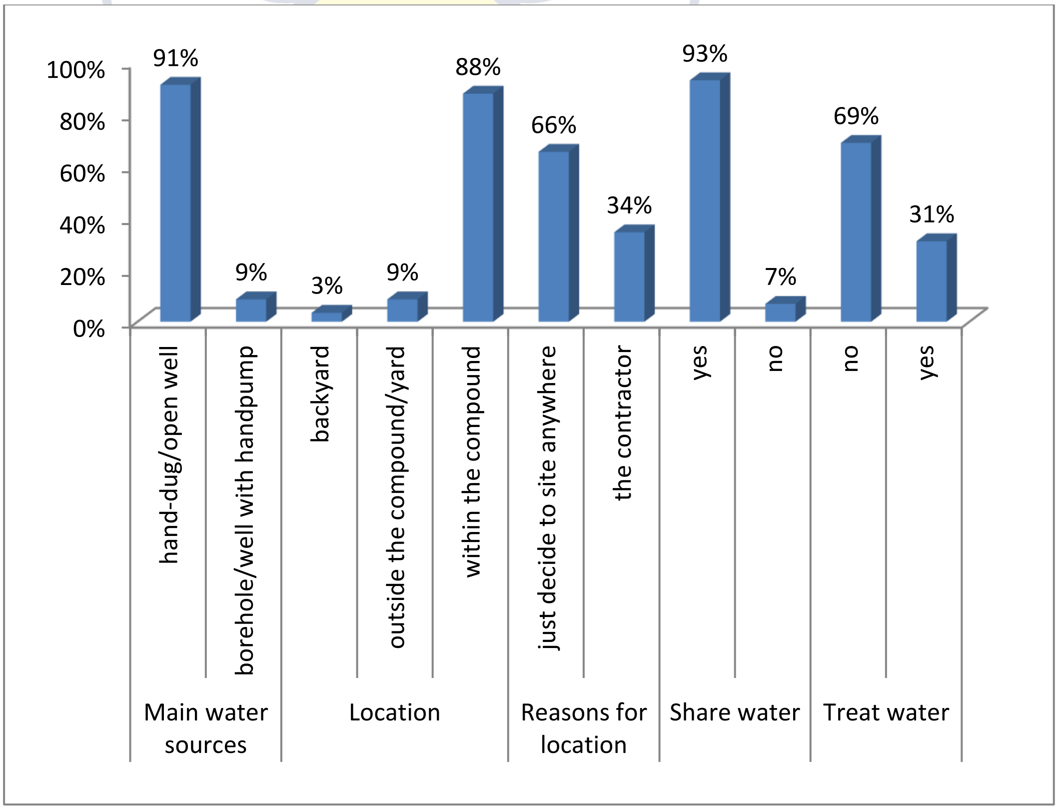

Figure 3:Water sources, Locations and Treatment

Source: Field Survey (2020)

4.3 Time and Cost of Getting Access to Water

The average number of days in a week of having access to water was 4days with 7days and a day been the maximum and minimum. Resident in the municipality can spend as large as 24 hours of getting access to water. The average hours spend was 5 hours. Most of the respondents have access to water in the morning of 41%, dawn 35% and afternoon 24%. None of the respondents gets water in the evening. Getting water every day is a problem in the municipality. Only a small number of people gets water daily with the majority of the people getting water more than thrice. From the table below, the majority of the people who have access to water in the morning fetch it thrice in a week. The average distance from house to standpipe was less than 1 km. The average volume of water collected per day was 125L. The average cost of water per trip in was ₵1.00 with people paying as high as ₵20.00. This implies that most of the households spent much money on water depending on the members of a household. This has negatively impacted on the economic development since much money is spent to acquire water and it would have been used in other productive activities. The source of funding for collecting water was mainly by the husband of 41%, relative 35, own funding 21% and none 3%. Unemployed people source of funding for the cost of water collection was either by relative or by husband this is because such people do not work and they are dependent. Majority of the people queue during the collection of water representing 58%, whiles 42% who do not. Of the gender, there was a slight difference concerning queuing. Figure 4.3 indicates there was a highly significant association between the queuing at the water source and the gender, with 30% of female having to queue as compared to the males (26%). Females queue more than males. Females are frequently involved gender in water collection. In queuing for the water, they spend a lot of time which would have been used in other development activities. The highest time spent in fetching water was 10 hours.

Table 3:Time of Getting Access to Water

Time perio	Times of fetching water in a week					
	Everyda	More than thrice	Once	Thrice	Twice	Grand Total
Dawn	2	12	5	5	11	35
Morning	2	15	4	12	8	41
Afternoon	0	7	3	7	7	24
Grand Tota	4	34	12	24	26	100

Source: Field Survey (2020)

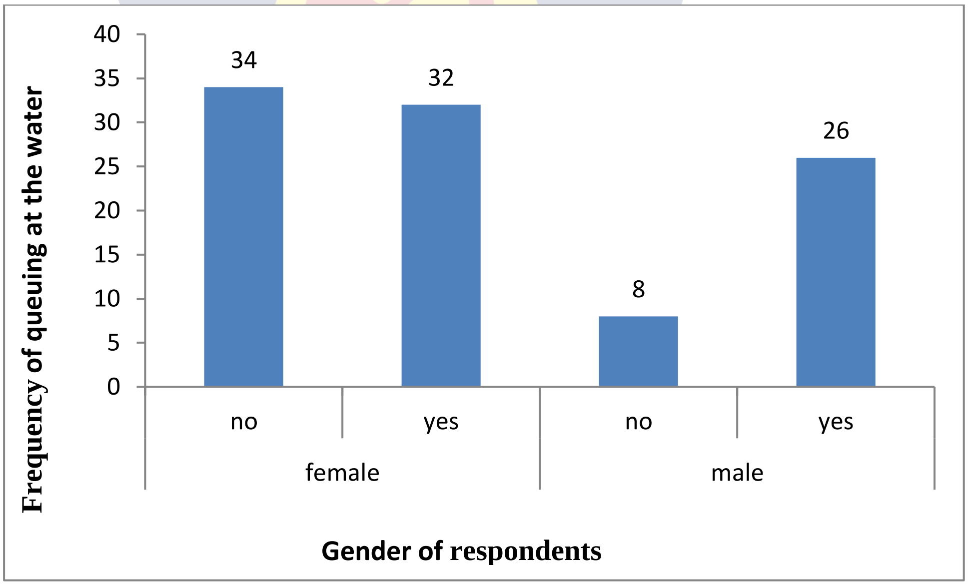

Figure 4:Relationship Between Queuing at the Water Points and the Gender

Source: Field Survey (2020)

4.4 Causes of Erratic Water Supply

According to an interview with Water Officers from the Municipal, High population was the major cause of erratic water supply since the increase in the water demand only translates to reduced levels of the resource and thus not always available due to rapid water withdrawal. The majority of the respondents attributed the erratic water supply to power rationing since most of the water pumps use electricity to pump it up to the buildings using electricity. Frequent power rationing then translates to erratic water supply since water is only pumped when there is power. From the analysis power irregularities, 75% was the main cause of erratic water supply since the power supply was not constant and therefore water has very little force to move up the water table and higher distances. This may be the main reason why water does not flow in the afternoon. It has been observed that the power supply in the afternoon is on and off. Though the solar system has been constructed to help in water distribution the strength of it is not enough to pump water to various communities. With the solar system, water force is very minimal for the water to move up the system translating to no water in the pipes and taps until the pressure is higher when the water level goes up. This may take longer especially during the dry seasons resulting in prolonged lack of water in the system and may require electricity to pump up the water. Leakages and busting of water transmission pipes were other cause of erratic water supply. Lack of operation and maintenance of water supply schemes (a matter of management and governance) is a major important cause for inadequate water supply globally (GoK, 2000). In urban areas water loss through leakage is a major factor reducing the quantity. The leakage occurs mainly due to corroded pipes in distribution network, damages caused during road widening and repair works and also use of poor-quality pipes in majority of household connections (Ngigi & Macharia, 2006).

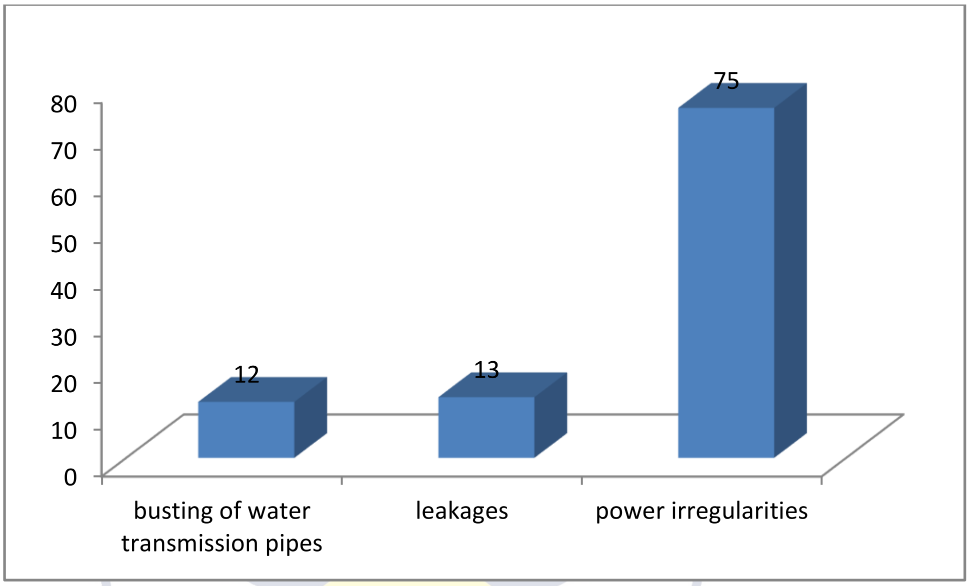

Figure 5:Causes of Erratic Water Supply

Source: Field Survey (2020)

4.5 Effects of Erratic Water Supply on Women and Children

There are various impacts of erratic water supply in the area. People resort to other sources of water such as streams, rivers, boreholes and wells for daily consumption when the supply of pipe water is not flowing. When such water sources are unsafe it will result in other water-related diseases. From discussion with the respondents, many of them said contraction of waterborne related diseases such as cholera, diarrhoea and typhoid were the main diseases people contract when they use unsafe water. Sources of water from direct surface waters that is rivers, lakes, ponds, etc. and unprotected wells and springs are regarded as unimproved water sources (UNICEF and WHO, 2008) and as such their daily consumption expose the individual to water-related disease. Sufficient supply of pipe water in the area would reduce the occurrences of the mentioned water-borne diseases. According to Antao *et. al.*, (2007), shortage of pipe water supply has resulted to reduced safe drinking water thus an increase in water-borne diseases in Kenya. The ingestion of water contaminated by faecal material infects people with viruses such as hepatitis, bacteria such as cholera, typhoid and dysentery, and parasites such as amoeba in most parts of the world (DfID *et al.*, 2002). This has resulted to death when the contamination is severe. For example, in India alone; nearly one million people die annually from water-borne diseases (World Bank, 2001). Another effect of erratic water supply was poor sanitation. Erratic water supply results in poor sanitation. Water shortage has a major effect on the sanitation of an area especially in the urban according to Kimani *et al.*, (2007). Conflicts also occur when there is erratic water supply. The conflicts are due to water shortage, overcrowding at water collection points (they are few) and theft of water containers and prolonged queuing time. The chi-square statistical test showed that there was no significant association between water conflicts and gender. According to Janakarajan (2002), water shortage is a major cause of conflicts in most areas globally being a basic resource.

Table 4:Effects of Erratic Water Supply on Women and Children

Parameter	Percentage
Water borne related diseases	55
Poor sanitation	30
Conflict	15

Source: Field Survey (2020)

4.6 Toilet Facility

More than 40% of the world's population did not have access to a toilet by the end of 2011 (WHO/UNICEF, 2013). The table below revealed that majority of the respondents use pit latrine of 20(39%), KVIP/VIP of 16(31%), Flush/WC toilet with a septic tank of 13(26%) and Flush/WC toilet with biofilm/digester of 2(4%). Thrift, (2007) stated that flush toilets seem to be used by a huge portion of the Ghanaians, with KVIP latrines being the major public toilet. Although Ghana ranks 152 out of 182 on the Human Development Index, it has the fourth-lowest rate of sanitation coverage worldwide (Water and Sanitation Sector Monitoring Platform, 2012). In 2005, the percentage of the population in Ghana with access to improved toilet facilities was approximately 40 per cent in urban areas and 35 per cent in rural areas (GWSRS, 2005). For the location of the toilet facility, most of the toilet facilities were located within the compound of 27(54%), outside the compound/yard were 15(30%) and 8(16%) were located at the backyard. For the setting of the toilet facility; 38(76%) just decided to site anywhere, 8(16%) were site by Environmental officer and 4(8%) were site by contractor.

Table 5:Type, Location and Reasons for the Site of a Toilet Facility

Factor	Response	Percentage
Type of toilet	Flush/WC toilet with septic tank	26%
	Pit latrine	39%
	KVIP/VIP	31%
	Flush/WC toilet with biofilm/digester	4%
Location	Outside the compound/yard	30%
	Within the compound	54%
	Backyard	16%
Reasons	Environmental officer	16%
	Just decided to site anywhere	76%
	Contractor	8%

Source: Field Survey (2020)

4.7 Nature of Septic Tank

Septic tanks typically hold the solids compartment of wastes in a sealed tank where the matter decomposes anaerobically; the liquid effluent is usually discharged into a soak-away. The above graph signifies that; 59% had no connection of septic tank to soak away, 38% had connection of septic tank to soak away, 2% don't know and 2% not sure. The connection of septic tank to a soakaway pit is important such that water is absorb and prevented from getting into the ground. This thus prevents contamination by the liquid effluent. Since majority of the respondents' septic tank was not connected to soakaway pit, it can be deduced that there is a possibility of groundwater contamination by the liquid effluent. For the location of the liquid effluent, 82% were buried underground and 18% were discharged on the land surface. For the flow of effluent 86% were discharged on the land surface while 14% were discharged into nearby drains. Discharging of effluent on the land surface and into nearby drains is not acceptable forms since there can be contamination.

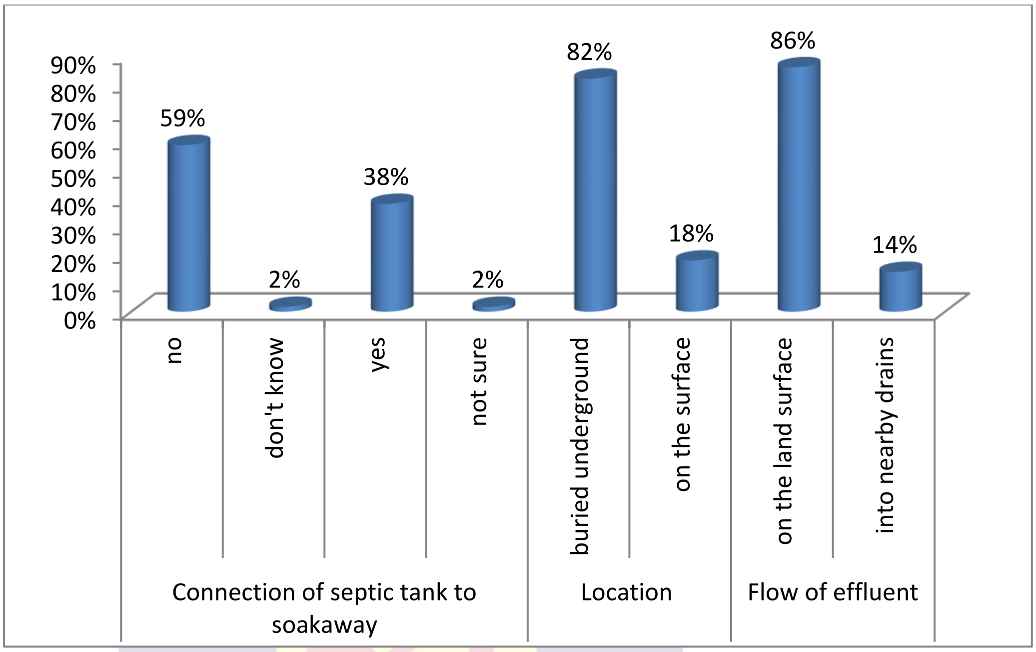

Figure 6:Nature of Septic Tank

Source: Field Survey (2020)

4.8 Greywater Disposal

Greywater disposal is dependent on the source of greywater. From the table above, the disposal of grey water by respondents are shown below; 31 respondents representing 53% dispose onto the compound, 9(16%) into drains/gutters, 7 (12%) into bushes, 5(9%) onto streets/open, 4(7%) connected to septic tanks/toilet pit, 1(2%) on the land surface and 1(2%) into gardens/lawns. The location of the soakaway for greywater was as follows; 21(47%) were within the compound, 15(33%) were outside the compound and 9(20%) were at the backyard. For the reasons for the location 41 (91%) just decided to site anywhere and 4(9%) were decided by a contractor. Disposal of greywater in other forms other than into gardens are not good, since greywater is often dependable sources of water, and they contain the nutrients which when used for a plant is very vital for plant growth (WHO, 2006). A sandy, well-drained soil will be less affected by greywater application than poorly-drained clay soil (Jeppersen & Solley, (1994). The poor disposal of greywater by respondents therefore implies that respondents need to store if its usage is not needed currently. Treating and storing of greywater will help respondents to use it when the needs arise.

Table 6:Grey Water Disposal

Factor	Response	Frequency	Percentage
Greywater disposal	on the land surface	1	2%
	into drains/gutters	9	16%
	connected to septic tank/toilet pit	4	7%
	onto street/open	5	9%
	onto compound	31	53%
	into nearby bushes	7	12%
	into gardens/lawns	1	2%
Location of soak away for greywater	outside the compound/yard	15	33%
	within the compound	21	47%
	backyard	9	20%
Reasons for the location	just decide to site anywhere	41	91%
	contractor	4	9%

Source: Field Survey (2020)

4.9 Distance from Pollution Source on Water Quality

According to Odai and Dugbantey (2003), in Ghana there is no law governing the arrangement of on-site sanitation and groundwater tapping points in a private compound. Odai and Dugbantey (2003) stated that the pollution levels in groundwater sources depend on the distance between the groundwater supplies and the pit latrines. The average distance of toilet to water facility in the house was 23cm with 90cm and 6cm been maximum and minimum. Again, the average distance from the septic tank/bio fill installation to water facility was 17.4cm with 40cm and 1cm been the maximum and minimum. The average distance of soakaway of septic tank installation to water facility was 16.12cm with 40 and 5 being the maximum and minimum. The average distance from greywater soakaway to water facility pit was 15.02 with 40cm and 2cm been the maximum and minimum. From a neighbour bordering on the north of respondents' resident, the average distance from neighbour's toilet facility to the water facility was 21cm with 36cm and 6cm been the maximum and minimum. Again, the average distance from septic tank/bio fill installation to water facility was 40.25cm with 215cm and 17cm been the maximum and minimum. The average distance of soakaway of septic tank installation to water facility was 21.5cm with 35 and 10 being the maximum and minimum. The average distance from greywater soakaway to water facility pit was 21.68 with 60cm and 3cm been the maximum and minimum. From a neighbour bordering on the south of respondents' resident Average distance from neighbour's toilet facility to the water, the facility was 34cm with 72cm and 12cm been the maximum and minimum. Again, the average distance from septic tank/bio fill installation to water facility was 25.8cm with 35cm and 17cm been the maximum and minimum. The average distance of soakaway of septic tank installation to water facility was 22.5cm with 35 and 15 being the maximum and minimum. The average distance from greywater soakaway to water facility pit was 22.29 with 45cm and 7cm been the maximum and minimum. From a neighbour bordering on the east of respondents' resident Average distance from neighbour's toilet facility to the water, the facility was 36.78cm with 72cm and 19cm been the maximum and minimum. Again, the average distance from the septic tank/bio fill installation to water facility was 36.83cm with 45cm and 25cm been the maximum and minimum. The average distance of soakaway of septic tank installation to water facility was 35.37cm with 65 and 20 being the maximum and minimum. The average distance from greywater soakaway to water facility pit was 29.66 with 60cm and 10cm been the maximum and minimum. From a neighbour boudering on the west of respondents' resident Average distance from neighbor's toilet facility to the water facility was 42.24cm with 87cm and 15cm been the maximum and minimum. Again, the average distance from the septic tank/bio fill installation to water facility was 31.4cm with 49cm and 16cm been the maximum and minimum. The average distance of soakaway of septic tank installation to water facility was 38.67cm with 90 and 17 being the maximum and minimum. The average distance from greywater soakaway to water facility pit was 28.44 with 87cm and 10cm been the maximum and minimum. Available literature maintains that increased lateral separation between a pollution source and groundwater supply reduces the risk of faecal pollution. Hence, the farther a groundwater supply is from the pollution source the less the risk of pollution (ARGOSS, 2001). Odai and Dugbantey (2003) studied the concentration of selected contaminants concerning the distances between the groundwater supplies and the on-site sanitation systems. The contaminants analysed were faecal coliform, nitrate, and chloride because they are key indicators of the presence of faecal pollution. The results were that: the levels of faecal coliform were highest in the wells at distances 25m and 46m, respectively from on-site sanitation. The well at a distance of 49m away from a pit latrine, was, however, less polluted.

4.10 Microbiological Quality of Water Samples

The WHO recommends that, for water to be considered no risk to human health, the total coliform bacteria, faecal coliform and *E. coli* in water sample should be zero (WHO, 2008). The values of Ecoli ranged from 19.56 to 62.75 MPN/100 ml. Site C recorded the highest value of 62.75 MPN/100 ml and Site D recorded the lowest of 19.56 MPN/100 ml. There was no significance difference (P>0.05) between the E.coli levels from the various places where water samples were drawn for the analysis. Salmonella values ranged from 40.25 to 83.75 MPN/100 ml. Again, Site B recorded the highest of 83.75 MPN/100 ml and Site C recoded the lowest of 40.25 MPN/100 ml. There was no significant difference (P>0.05) between the salmonella levels from the various places where water samples were drawn for the analysis. Klebsiella (total coliforms) ranged from 46.67 to 75.44 MPN/100 ml. Highest value was recorded by Site A of 75.44 MPN/100 ml and the lowest by Site D of 46.67 MPN/100 ml. There was no significant difference (P<0.05) between the Klebsiella (total coliforms) levels from the various places where water samples were drawn for the analysis. These results do not conform to the WHO and Ghana Standard Board guideline value of 0 MPN/100 ml. In Appiah and Momende (2010) studies, they indicated that the possible cause of high values of bacteria was that there were leakages of contaminated water to the well. The results agreed with most of the literature (Odai and Dugbantey, 2003) with the assertion that proximity in terms of lateral distance of the site of hand-dug wells to pollution source; in this case, the pit latrine may necessarily pose a risk of contamination. The findings however agreed with ARGOSS (2001) that maintains that increased lateral separation between a pollution source and groundwater supply reduces the risk of faecal pollution. Appiah and Momende (2010), stated that poorly made concrete apron and water run-off into crack will allow leakage of wastewater from the surface back into the well to contaminate it may be able to be associated with this finding. Buckets and ropes which are used to draw the water, often lie around the unhygienic rim of the well may contaminate the water (Appiah & Momende, 2010).

Table 7:Mean ± SD Levels of Bacteria in Hand-Dug Well

	Mean Values of microbes in water samples		
Community	*E-coli*	*Salmonella*	*Klebsiella*
Site A	56.56±53.57	65.11±27.37	75.44±63.40
Site B	45.42±69.71	83.75±55.00	60.42±69.58
Site C	62.75±59.81	40.25±41.64	54.00±57.59
Site D	19.56±15.91	82.78±67.15	46.67±44.12
Site E	44.50±30.71	76.31±53.78	64.69±49.52
WHO Limit	0 MPN/100 ml	0 MPN/100 ml	0 MPN/100 ml
LSD	47.35NS	51.87NS	56.62

Source: Field Survey (2020)

4.12 Physico-Chemical Parameters of Water Samples

The values of pH ranged from 4.893 to 5.647. Site E recorded the highest value of 5.647 and Site A recorded the lowest of 4.893. There was no significant difference ($P>0.05$) between the pH levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of pH content in water of 6.5-8.5. Appiah and Momende (2010) reported that all the hand-dug wells they studied in Kintampo had pH values of 5.5 to 6.5. The findings of Appiah and Momende (2010) and that of this study of were all with the WHO/GSB permissible value and the results are similar since the water samples were taken from the same community and hence have similar environmental conditions. In a separate study by Darko-Mantey *et al.*, (2005), on drinking water from different sources, they observed a pH range of 6.1 to 7.2. Darko-Mantey *et al.*, (2005). The findings of these authors were slightly different from the findings of this study due to the fact that the samples were from different communities where different environmental conditions pertain. Turbidity values ranged from 1.56 to 9.85. Again, Site C recorded the highest of 9.85 and Site D recoded the lowest of 1.56. There was no significance difference ($P>0.05$) between the turbidity levels from the various places where water samples were drawn for the analysis. Site C and Site E values obtained were above the WHO limit of turbidity content in water of 5. EC ranged from 151.10 µS/cm to 358.37 µS/cm. Highest value was recorded by Site B of 358.37 µS/cm and the lowest by Site D of 151.10 µS/cm. There was no significance difference ($P>0.05$) between the EC levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of EC content in water of 300 µS/cm. The turbidity and EC ranged values obtained were lower than that of Appiah and Momende (2010) study in Kintampo where they had values turbidity range of 0.4 to 23.5 NTU; conductivity range of between 420 µS/cm to 5180 µS/cm with a mean of 1737.1 µS/cm. TDS ranged from 79.78 to 184.24. Highest value was recorded by Site B of 184.24 and the lowest by Site D of 79.78. There was no significance difference ($P>0.05$) between the TDS levels from the various places where water samples were drawn for the analysis.

The values obtained were below the WHO limit of TDS content in water of 1000. Nitrate ranged from 0.1544 to 0.3667. The highest value was recorded by Site B of 0.3667and the lowest by Site E of 0.1544. There was no significant difference (P>0.05) between the nitrate's levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of nitrate content in water of 50. Phosphorus ranged from 0.0100 to 0.04063. The highest value was recorded by Site E of 0.04063 and the lowest by Site D of 0.0100. There was no significant difference (P>0.05) between the nitrate's levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of phosphorus content in water of 0.3. High values recorded for turbidity, EC, TDS and for other parameters like nitrate and phosphorus occurred due to infiltration of runoffs into the wells. In some wells, particularly drive-point wells or other shallow wells, nitrate may only be present during the spring or after a heavy rainfall when rapid infiltration of surface water occurs. Because nitrate can move rapidly down through the soil into the groundwater, the presence of nitrate may provide an early warning of possible problems and can sometimes indicate the presence of other contaminants (Minnesota Department of Health, 2010).

Table 8:Levels of Physico-Chemical Parameters of Water Samples

	Mean Values of physico-chemical in water samples					
Community	pH	Turbidity	EC	TDS	Nitrate	Phosphorus
Site A	4.893±1.19	2.34±1.44	302.80±156.3	156.75±80.09	0.2956±0.28	0.02556±0.26
Site B	5.562±0.54	2.42±1.25	358.37±211.15	184.28±108.59	0.3667±0.30	0.03667±0.033
Site C	5.122±1.06	9.85±6.82	336.42±185.49	109.22±77.64	0.3000±0.21	0.02500±0.021
Site D	5.528±0.37	1.56±0.56	155.70±113.255	79.78±58.36	0.2333±0.26	0.01000±0.03
Site E	5.647±0.23	8.64±7.59	151.10±118.43	83.95±65.55	0.1544±0.37	0.04063±0.02
WHO Limit	6.5-8.5	5	300µS/cm	1000	50	0.3
LSD	0.6574NS	4.751NS	154.7NS	79.44NS	0.3075NS	0.02663NS

Source: Field Survey (2020)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The study sought to investigate the physical, chemical, and bacteriological quality of hand-dug wells sited close to latrines at Ketu South Municipality, and whether they meet international and local water quality standards set by WHO and GSB, respectively. The study revealed that the main water sources of the respondents were hand-dug/open well representing 91% and the least water sources were borehole/well with a hand pump of 9%. The location of the main sources of water; 88% were within the compound, 9% were outside the compound/yard and 3%. For the reasons for the location of the main sources of water; 66% just decide to site anywhere while 34% were constructed by contractors. Respondents who share their water source with others (Yes) were 93% while 7% do not share their water with others (No). For the treatment of water, 69% of the respondents do not treat their water while 31% treat their water. Majority of the respondents use pit latrine of 20(39%), KVIP/VIP of 16(31%), Flush/WC toilet with septic tank of 13(26%) and Flush/WC toilet with biofilm/digester of 2(4%). For the location of the toilet facility, most of the toilet facilities were located within the compound of 27(54%), outside the compound/yard were 15(30%) and 8(16%) were located at the backyard. For the setting of the toilet facility; 38(76%) just decided to site anywhere, 8(16%) were site by Environmental officer and 4(8%) were site by contractor. About 59% had no connection of septic tank to soak away, 38% had connection of septic tank to soak away, 2% don't know and 2% not sure. For the location of the liquid effluent, 82% were buried underground and 18%

were discharged on the land surface. For the flow of effluent 86% were discharged on the land surface while 14% were discharged into nearby drains. Discharging of effluent on the land surface and into nearby drains is not acceptable forms since there can be contamination. The disposal of greywater by respondents are shown below; 31 respondents representing 53% dispose onto the compound, 9(16%) into drains/gutters, 7 (12%) into bushes, 5(9%) onto streets/open, 4(7%) connected to septic tanks/toilet pit, 1(2%) on the land surface and 1(2%) into gardens/lawns. The location of the soakaway for greywater was as follows; 21(47%) were within the compound, 15(33%) were outside the compound and 9(20%) were at the backyard. For the reasons for the location 41 (91%) just decided to site anywhere and 4(9%) were decided by a contractor. The values of pH ranged from 4.893 to 5.647. Site E recorded the highest value of 5.647 and Site A recorded the lowest of 4.893. There was no significance difference (P>0.05) between the pH levels from the various places where water samples were drawn for the analysis. The values obtained were below the

WHO limit of pH content in water of 6.5-8.5? Turbidity values ranged from 1.56 to 9.85. Again, Site C recorded the highest of 9.85 and Site D recoded the lower of 1.56. There was no significant difference (P>0.05) between the turbidity levels from the various places where water samples were drawn for the analysis. Site C and Site E values obtained were above the WHO limit of turbidity content in water of 5. EC ranged from 151.10 μS/cm to 358.37 μS/cm. The highest value was recorded by Site B of 358.37 μS/cm and the lowest by Site D of 151.10 μS/cm. There was no significant difference (P>0.05) between the EC levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of EC content in water of 300 µS/cm. TDS ranged from 79.78 to 184.24. The highest value was recorded by Site B of 184.24 and the lowest by Site D of 79.78. There was no significant difference (P>0.05) between the TDS levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of TDS content in water of 1000. Nitrate ranged from 0.1544 to 0.3667. The highest value was recorded by Site B of 0.3667and the lowest by Site E of 0.1544. There was no significant difference (P>0.05) between the nitrate's levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of nitrate content in water of 50. Phosphorus ranged from 0.0100 to 0.04063. The highest value was recorded by Site E of 0. significance difference (P>0.05) between the nitrate's levels from the various places where water samples were drawn for the analysis. The values obtained were below the WHO limit of phosphorus content in water of 0.3.

5.2 Conclusion

There were accesses to water and sanitation facilities were very high. All respondents have access to water sources by all the respondents. Whiles majority have water sources in their compound others access it outside the compounds. Treatment of water was not done in most households. Positioning of toilet was mostly not done with the help of expert (Environmental Health Officer) advice and disposal of effluent was very poor. Water quality parameters analyzed in the water samples were below the WHO limit for drinking water making the water sources acceptable for drinking.

5.3 Recommendations

From the analysis, it is recommended that:

1. The water and sanitation programme of the Municipal Assembly should encourage house owners with private hand-dug wells to routinely treat their well with chlorine tablets.
2. The Water and Sanitation Team should educate owners of private hand-dug wells to keep the head of their wells clean and routinely disinfect the well.
3. The Environmental Health Unit of the Municipal Assembly should encourage people to approach them for advice on where to site household latrine.
4. The Water Supply should take steps to reduce the chloride and calcium concentrations in their water since these ions contribute to the taste and hardness in the water.
5. The water and sanitation programme of the Municipal Assembly should enforce by-laws on the minimum lateral distance of 20 m between a latrine and well water.
6. The implementation of regulations on safe drinking water by the Ghana Standards Board, the Ghana EPA and district environmental units and other state enforcement agencies will go a long way to reduce incidences of water pollution and the associated water-borne diseases.
7. Further research on other communities in the District for the assessment of the quality of drinking water is required as levels of contaminants may vary due to different soil types, water chemistry and different human activities.

REFERENCES

Abbou, B.M., Haji, M.E., Zemzami, M., Bougarne, L., Majdoub, I.L. & Fadil, F. (2014). Assessment of Groundwater Chemistry and Bacteriology in the Couloir Fes-Taza Aquifer. *International Journal of Farming & Allied Science, 3(10): 1092-1099.*

Adetunji, V. O., & Odetown, I. A. (2011). Groundwater contamination in Agbowo community, Ibadan Nigeria; Impact of septic tanks distances to wells. *Malaysian Journal of Microbiology. 7 (3):159 -166.*

Agyekum, W.A. & Dapaah-Siakwan, S. (2008). *The Occurrence of Groundwater in north-eastern Ghana,In: Applied Groundwater Studies in Africa*. International Association of Hydrogeologists selected papers. DFID, Taylor & Francis group; pp. 199-206.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., & Bartram, J. (2014). Fecal contamination of drinking-water in low-and middle-income countries: a systematic review and meta-analysis. *PLoS medicine 11(4)*:

Basu, N. & Van Meter, K. (2014). *Comprehensive Water Quality and Purification - Sustainability of Groundwater Resources*. Volume 4; pp. 57-75. Published by Elsevier Inc.

Bloomfield, S.F. (2012). The *chain of infection transmission in the home and everyday life settings, and the role of hygiene in reducing the risk of infection*. Simmons College, Boston, MA USA

Bonsor, H. C. and MacDonald, A. M. (2010). Groundwater and Climate Change in Africa: *Review of Aquifer Property Data.* Groundwater Science Programme Internal report IR/10/076; pp. 4-13. Published by Natural Environmental Research Council.

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P. S. and Wichman, M. (2007). Impact of Waste from Concentrated Animal Feeding Operations on Water Quality. *Environmental Health Perspective*, *115 (2): 308-312.*

Department of Water Affairs and Forestry, DWAF. (2003). *A Protocol to Manage the Potential of Groundwater Contamination from On-site Sanitation*. National Sanitation Programme, 2nd Edition, DWAF; pp. 5-36.

Department of Water Affairs and Forestry, DWAF. (2004). *Groundwater Protection: Guidelines for Protecting Boreholes and Wells. Toolkit for Water Services*. Number 3.3, DWAF; pp. 1-10.

Diabene, P. Y. and Gyamfi, C. (2014). Groundwater Potential for Rural Water Supply: A Sustainability Assessment of Boreholes in the Bawku West District, Ghana. *Journal of Environmental Science and Water Resources*, *3 (5): 110-117.*

Epworth Case Study Article. Retrieved On 28/01/2019 from Httpi//Www.Ncbi.N/M.Nih. Gov/ Pubmed//084 28

Foster, S., Chilton, J., Nijsten, G. and Richts, A. (2013). *Groundwater – A Global Focus on the Local resource*. Current Opinion in Environmental Sustainability, 5(6). Published by Elsevier B.V.

Freshwater Society, (2013). Minnesota's Groundwater: Is Our Use Sustainable? A Freshwater Society special report/April 2013.

Ghana Statistical Service. (2000). Ghana Living Standards Survey. www.worldbank.org/html/prdph/lsms/country/gh/docs/G4report.pdf.

GWSRS, (2005). *Ghana Water Sector Restructuring Secretariat Report*. Accra, Ghana.

Hornsby A.G (2003). *How Contaminants Reach Groundwater*; Paper Sl143 Retrieved on 11/02/19 from Http: Lledis-:Fas-Ufl.Edu/Ss194.

International Groundwater Resource Assessment Centre, IGRAC. (2004). The World's Groundwater Resources – *Contribution to Chapter 4 of WWDR-2 (draft)*. Report Nr IP 2004-1.

Jessoe, K. (2013). Improved source, improved quality? Demand for drinking water quality in rural India. *Journal of Environmental Economics and Management 66: 460-475*

Kanyere, T., Levy, J., Yongxin, X., & Saka, J. (2012). Assessment of microbial contamination of groundwater in upper Limphase River catchment located in a rural area of Northern Malawi. *Water SA; 2012:38. 581-596.*

Kimani-Murage E. & Ngindu A.M (2003), Quality of Water the Slum Dwellers Use: the Case of a Korgan Slum. *Urban Health Journal, 84(6):829-38*, Retrieved on 10/02/19 from http://www.ncbi.nlm-n;h-gov/pubmed/17551841.

Kyakula, M., Okiror, S., & Kawesa, P. (2015). Elimination of Pollution of Groundwater by On-Site Sanitation Systems. *Journal of Water Resource and Protection*, 7, 1449-1456.

Lennetech, (2013). *Sources of groundwater pollution; 2013*. Accessed 20 November, 2019. http://www.lenntech.com/groundwater/pollution-sources.htm

Liu, L., Johnson, H. L., Cousens, S., Perin, J., Scott, S., Lawn, J.E., Rudan, I., Campbell, H., Cibulskis, R., Li, M., Mathers, C., & Black, R. E. (2012). *Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000.* The Child Health Epidemiology Reference Group of WHO and UNICEF; 2012. Geneva

MacDonald, A. M. and Davies, J. (2000). *A Brief Review of Groundwater for Rural Water Supply in sub-Saharan Africa. Technical Report WC/00/33 – Overseas Geology Series*. Published by British Geological Survey on behalf of DFID.

MacDonald, A. M., Bonsor, H. C., Dochartaigh, B. É. O. and Taylor, R.G. (2012). *Quantitative Maps of Groundwater Resources in Africa. Environmental Research Letter*. volume 7/024009. Published by IOP Publishing Ltd.http://www.iopscience.iop.org/1748-9326/7/2/024009

Martin, N. and Van de Giesen, N. (2005). Spatial Distribution of Groundwater Production in the Volta River Basin of Ghana and Burkina Faso. IWRA. *Water International, 30(2): 239-249*

Mtine, M. (2010). *Zambia Cholera Outbreaks*; Web Article. Retrieved on 20/07/20 from Htt://Www.Flutracters.Co / Forum/Showthread.Php^T=139591

Nyarko, A. A. (2008). *Assessment of Groundwater Quality and Urban Water Provision: A Case of Taifa Township in the Ga-East District of the Greater Accra Region, Ghana*. Master of Science Thesis, Department of Environmental Science, College of Science, KNUST, Kumasi.

Obuobie, E. & Barry, B. (2010). Groundwater in Sub-Saharan Africa: Implications for Food Security and Livelihood. Final Report on Status of Groundwater in Ghana.

Obuobie, E., Diekkrueger, B., Agyekum, W. and Agodzo, S. (2012). Groundwater Level Monitoring and Recharge Estimation in the White Volta River basin in Ghana. *Journal of African Earth Sciences, 71: 80-86*

Rusinga, F. (2004). *Protection of Groundwater from Contamination by Pit Latrines in: Protecting Groundwater from Contamination*. Toolkit for Water Services: number 3.4.4. Published by DWAF, Pretoria 0001.

Russel, B. J. and Jon, G. S. (2004). *Practical Handbook of Soil, Vadose zone and Groundwater Contamination. Assessment, Prevention and Remediation*, 2nd Edition. Lewis Publishing.

Sandhyarani, N. (2018). Groundwater pollution; 2009. (Accessed 21 November, 2018. http://www.buzzle.com/articles/groundwater-pollution.html)

Shivendra, B. T. & Ramaraju, H. K. (2015). Impact of onsite sanitation system on groundwater in different geological settings of peri urban areas. *Elsevier Science Direct 4:* 1162–1172.

Siebert, S., Faures, J. M., Frenken, K., Hoogeveen, J., Doll, P. and Portmann, F. T. (2010). *Groundwater Use for Irrigation – a global inventory*. Published by Copernicus Publications on behalf of the European Geosciences Union. Hydrology and Earth System Sciences, 14, 1863-1880, 2010.

Sorensen, J. P. R., Sadhu, A., Sampath, G., Sugden, S., Gupta, S.D.; Lapworth, D. J; Marchant, B. P. and Pedley, S. (2015). Are sanitation interventions a threat to drinking water supplies in rural India? An application of tryptophan-like fluorescence. *Elsservier Water Research 88: 923-932*

Still, D.A. and Nash, S.R., (2002). *Groundwater Contamination Due to Pit Latrires Located in a Sandy Aquifer; A Case Study from Maputaland*; Retrieved On 11/02/19

from http://www.ssw.info/sites/default/files/references-eattachments.

Sugden S., (2006). The Microbiological Contamination Of Water Supplies, Sandy Cairncross; Well Factsheet. Retrieved from http://www.lboro.ac.uk/well/resource/fact-sheets/fact-sheet-htm/contamination.htm on 9/06/19

Szabo, J. & Minamyer, S. (2014). *Decontamination of biological agents from drinking water infrastructure: A literature review and summary*.

Thrift, C. (2007). *Sanitation Policy in Ghana*: Key Factors and the Potential for Ecological Sanitation Solutions

UN Secretariat. (2013). *UN Millennium Development Goals Report 2013.* (Retrieved on 18th October, 2020 from http://www.un.org/millenniumgoals/pdf/report-2013/mdg-report-2013-english.pdf)

Usaharani, K., Umarani K., Ayyasamy P. M., Shanthi K., & Lakshmanaperumalsamy P. (2010). Physico-Chemical and Bacteriological Characteristics of Noyyal River and Ground Water Quality of Perur, India. *J. Appl. Sci. Environ. Manage, 14(2); pp 29-35.*

Water and Sanitation Sector Monitoring Platform, (2012). *Water and Sanitation Sector Overview 2012*. Accra: Water and Sanitation Sector Monitoring Platform.

WHO/UNICEF, (2013). *Joint Monitoring Programme for Water Supply and Sanitation: Progress on Drinking Water and Sanitation – 2013 Update*. Geneva: WHO Press.

WHO/UNICEF. Joint Monitoring Programme (JMP) (2008). *Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade*. Geneva http://www.who.int/water_sanitation_health/monitoring/jmpfinal.pdf.

World Health Organization (WHO). (2014). *Progress on Drinking Water and Sanitation*. Geneva

World Health Organization (WHO). (2011). *Guidelines for drinking-water quality*. Geneva

World Health Organization (WHO). (2013). *Water quality and health strategy 2013-2020*. Geneva

Xu, Y. and Usher, B. (2006). *Issues of Groundwater Pollution in Africa in: Groundwater Pollution in Africa*. Published by Taylor and Francis/Balkema.

APPENDIX A

Plate 1: Standpipe at Hatsukope in the Ketu-South Municipality

Plate 2: Hand-dug well at Akame

Plate 4: Bore-hole at Laklivikope