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ASSESSING THE QUALITY OF HOUSEHOLD HARVESTED RAINWATER IN THE ASSIN SOUTH DISTRICT OF THE CENTRAL REGION OF GHANA

BENJAMIN KINGSFORD WIREDU

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ASSESSING THE QUALITY OF HOUSEHOLD HARVESTED RAINWATER IN

THE ASSIN SOUTH DISTRICT OF THE CENTRAL REGION OF GHANA

BENJAMIN KINGSFORD WIREDU (BA ENVIRONMENT AND RESOURCE MANAGEMENT)

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SUBMITTED TO GRADUATE SCHOOL, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL) IN DEVELOPMENT STUDIES.

OCTOBER, 2019

DECLARATION

Student

I thereby declare that this thesis is the result of my own original work and that no part of

it has been presented for another degree in this university or else:

Candidate's Signature:………………………………………

Date:…………………………

Name: **BENJAMIN KINGSFORD WIREDU**

Supervisor

I thereby declare that the preparation and presentation of the thesis was supervised in

accordance with the guidelines on supervision of thesis laid down by University for

Development Studies.

Supervisor's Signature:………………………………….

Date:………………………………

Name: **DR. EBENEZER OWUSU-SEKYERE**

ABSTRACT

Water is vital to human existent and human well-being. The availability of adequate standard, clean, safe and secured water source has been and would always be a major concern. Human access to adequate safe and secured fresh water is limited, yet crucial for the survival of livelihood and healthy living. Rainwater Harvesting (RWH) through the roof catchment is an important domestic water source. The RWH system consists of the capture, transporting pipes, storage and utilization of stored rainwater. The purpose of this study was to assess the quality of rainwater harvested in the Assin South District of the Central Region of Ghana. The study adopted multiple research methods including questionnaire survey, key informant interviews and laboratory analysis to determine the quality of rain water harvested in the District. The results show residents used roof surface as rainwater harvesting systems. The catchment surfaces were made up of 86% Aluminum Zinc, 4% coated Zinc, 7% was slate with only 1% made of bamboo and 2% coconut leaves. Again, the results further showed that the parameters for assessing water quality such as physico-chemical properties; micro biological properties and trace metal content were either above or below the World Health Organization and the Ghana Water company acceptable standards. The study also showed that the limited access to potable water supply could rise in the district as demand for water for both economic and domestic activities was increasing. It is therefore recommended that there was the need to develop a definitive or even a more sustainable water supply systems that are environmentally friendly, socially acceptable and economically viable.

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DEDICATION

I dedicate this thesis to my lovely wife Mrs. Linda Wiredu who has been my backbone and to the ever loving memory of my mother Madam Sophia Werekua Wiredu who sacrificed all resources to enable me attain education to the highest level. She sought to make me greater than herself. Abraham Lincoln once said "all that I am or ever hope to be, I owe to my mother" Sister Sophie was "the earliest, strongest, and most impacting force in my life" (Ben Carson, 1996). Her dedication made a profound impression on my life.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The ever increasing world population is threatened by the ever continuing water shortage problem. According to World Water Council (Ababio, 2010), the consumption of renewable water resources has grown six-fold in the 20th century responding to three times increase of the world population. It emphasized that the demand for water within the next fifty years will increase due to prediction of 40 to 50% population growth coupled with industrialization and urbanization, resulting in serious consequences on the environment too. Fresh water resources are depleting due to over-exploitation, water quality degradation, and climate change (Şen et al., 2011). The demand increases especially in water scarcity countries due to urbanization and the increasing population (Abayei, 2007). For instance, desalination technologies, although expensive, have been used in countries to overcome the excess water demand due to groundwater over-exploitation and seawater intrusion to the aquifers (Adamson, and Aberge, 1998). Mostly, the distribution of the water resources in many countries is not proportional to its need. According to Adedze (2005), the situation will become worse due to the heavy pressure on neighboring water resources placed by the rapid growth of urban areas. These areas become the end point for the urban water cycle because of the high consumption rate of blue water, being the water source of a river or groundwater aquifer.

Water is vital to human existent and also an important resource for development and above all human well-being (WHO, 2013; UNICEF, 2009). The availability of adequate standard,

clean, safe and secured water source has been and would always be a major global and local concern for all international, regional institutions and human populations (FAO, 2011). It is estimated that a person requires at least half a liter (0.11 gallons) of water in a day to meet basic survival needs and two liters (0.44 gallons) per day to quench thirst. However, a person needs 27 to 200 liters (6 to 44 gallons) per day for basic domestic needs including drinking, cooking, bathing and sanitation. Household water needs vary based on a number of factors such as total number of members in the household, the type of dwelling, lifestyle and type of plumbing works (WHO, 2013; UNICEF, 2009).

Human access to adequate safe and secured fresh water is limited, yet crucial for the survival of livelihood and healthy living. Fresh water is a renewable resource but limited in quantity, it is a scarce commodity in many parts of Africa and Asia because of unplanned withdrawal of waters from open surfaces (streams) and underground aquifers leading to severe environmental challenges like arsenic contamination (Adoma-Yeboah, 2005). Water scarcity occurs when the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, resulting in increased competition between water users and other demands (UNISDR, 2011). Water scarcity is global phenomenon. It may be explained geographically. It has been diagnosed that a lot of areas in the developing world, experience imbalances in the amount of water being consumed and the annual amount of aquifer recharge (renewal) i.e. the former greater than the latter, thus creating a non-sustainable scenario (Ahorlu, et al., 1997).

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In some parts of the globe, it is physical water scarcity because there are not enough resources of fresh water to supply the increasing demand. However, other parts of the world particularly Africa have an economic scarcity: it is the case where resources are more abundant but poor governance and management coupled with other problems creates the situation of water scarcity for most of the population, hence the poor paying more for potable water whiles the rich pays less for safe and secured water supply (Amenga-Etego, 2003). In situations of economic water scarcity, there are many solutions that could ameliorate the problem, but these solutions require a strong commitment from the state actors, injection of large capital into water delivery system, and some cases a change in government. Solving the water scarcity demands a long-term initiative; however, the need for water is immediate concern (UNISDR, 2011).

The visibly limited resources including human and capital as well as limited investment in the water sector to produce water from secured sources have compelled many of the population in developing world especially sub-Sahara African countries to depend on sources such as lakes, rivers, creeks, brooks, unprotected wells and water from reservoirs and wetland resources (Ampofo, 1988; WHO, 2017). Another source of water that has emerged as significantly important for both domestic and to some extent, industrial use is rain water harvesting (American Association of Respiratory Care, 2004).

Rain Water Harvesting (RWH) through the roof catchment is an important domestic water source not only in Ghana, but in many countries in the Global South (Asare-Boadu, 2002). It has gained prominence and its application is no more a supplement to other water sources

but a cardinal source of water (UNISDR, 2011). Rainwater harvested directly from the sky without any contact with any catchment surface is potentially safe but may be contaminated by its touch with surface areas and storage facilities employed in harvesting rainfall (Babb and Scherr, 2001). The quality of harvested rainwater as safe water is under the influence of the type of materials that constitute the storage systems (Bartone, 1991; Basoglu, et al., 2005; Baiquni, 2009). Rainwater harvesting has a lot of advantages: is a unique source for water provision and sustains the environment with no adverse effects and provides water at one's own abode, it is convenience in supply as compared to ground and surface water taking into account distance to sources of surface and ground water (Basta, 2015). Other studies further indicate that harvesting rainwater eradicate poverty, as women's livelihood are improved and saved the stress of travelling distances to fetch water; as they are fully responsible for household water provision (FAO, 2011).

The RWH system consists of the capture, transporting pipes, storage and utilization of stored rainwater, it is suitable for both potable and non-potable use (Beck, 2006). RWH systems supply water for households such as drinking, bathing, washing, flushing of toilet; agricultural activities including livestock, aquifer recharge, institutions and industries and also serve as flood control measures and an emergency supply for firefighting (Adamson, and Aberge, 1998; Abayei, 2007; Ababio, 2010). Rainwater Harvesting is promoted as part of the solution to poverty and environmental degradation. As part of efforts in promoting the RWH, in 1999, the International Environmental Technology Center of the United Nations Organization's Environment Programme featured sustainable drainage system and RWH in international symposium on efficient water use in urban areas. The focus was on

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water security through efficient use of the existing sources to avoid supply issues (Agyepong, 1998). Recommendations included the development of technologies; stimulation of public interest; production of government policy frameworks to address social, economic and environmental benefits; development of frameworks for sharing best practices; encouraging community participation and involvement of government and recognition of the role of individuals in environmental management. There is a rising interest in rainwater harvesting technology and the purpose of harvesting rainfall has changed from its ordinary function as mere household water supplement to major water source for domestic activities (UNISDR, 2011).

Rainwater harvesting in Ghana has historical antecedence. Records available proves that during the colonial regime, the missionary and government agencies adopted and are still practicing RWH (Beck, 2008). Organizations such as the Presbyterian Church, World Vision, and New Energy have promoted and undertaken extensively Rainwater harvesting (RWH) in the Northern Region of Ghana (Barnes, 2009). The persistent pressure from civil society groups including the Ghana Science Association (GSA) on the need to have a national legislation to make rainwater harvesting compulsory and landlords, builders, civil engineers, to incorporate into designs of buildings the rainwater harvesting systems compelled Ghana to pass the National Rainwater Harvesting Strategy, a component of the National Water Policy (Barnes, 2009). Rain water harvesting has been proven as possible one of the successful and inexpensive solutions for the vulnerable and large segment of our society for adequate water supply. Experiences from ages proves that rainwater harvesting system had been in existence and it is an innovative approach for the integrated and

sustainable development of the rural populations. The appropriateness of harvesting rainfall for domestic purposes as inexpensive alternative to many traditional water resources suggested by scientists and researchers globally seems to be the most attractive and a bright alternative for supplying fresh water in houses or institutions as water scarcity soars and water demand in Ghana keeps rising but however its quality demands inquiry (GSS, 2010).

1.2 Problem Statement

Available Annual Review Report (2014), of the Assin South District indicates that safe and secured drinking water is scarce in the District. This is due to the fact that many communities in the District are not on the national water grid and few communities are served by small town water supply system and has been facing water scarcity for years. For this reason, the common source of water supply for their both household and industrial water needs include rainfall, open streams, ponds, dug-outs and boreholes. These same sources also serve as the drinking sources for animals as well, therefore exposing the people to diseases and other health threats (GSS, 2010). Of all these sources, rainwater harvesting has emerged as the most popular source of water in the District. It has become a common phenomenon in Assin South District since the District falls under the evergreen and semi-deciduous forest zone where rainfall is relatively abundant and also well distributed throughout the year. Rainwater harvesting has been providing the long-term answers to the problem of water scarcity. Beyond being environmental friendly, there are a number of ways in which water harvesting has benefited the communities in the District. It has enabled efficient collection and storage of rainwater, made it accessible and helped smooth out variation in water availability by collecting the rain and storing it more efficiently in

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closed stores. In doing so, water harvesting assures a continuous and reliable access to water and also supplements household water demands. For instance, it is estimated that a storage cistern with the capacity of 16, 000 liters supplement other safe drinking water for household of five for a period of 10 to 12 months, a situation that not only liberate children, but also liberate women from trekking several meters in search of water (GSS, 2010).

Despite the significance of rainwater harvesting and the numerous calls from the international community to properly situate it within the broad water supply systems, what has often not attracted much academic attention is the quality of rainwater that have been collected and stored. The quality of water storage is important because as observed by Owusu-Sekyere et al. (2014), while water fetched directly from source may be pure and uncontaminated, the way water is stored, where it is stored and how stored water is fetched can lead to contaminations. Literature search to the best of the researcher's ability showed no empirical analysis regarding the quality of rainwater harvested within the district. The quality of harvested rainwater as potable water for household uses in the Assin South District of the Central Region of the Republic of Ghana has remained largely unaddressed although researchers have stressed the need for rainwater harvesting to boast water delivery in household levels. This thesis therefore aims at examining the harvested rain water quality in the Assin South District of the Central Region of the Republic of Ghana.

The thesis recognizes that there are three (3) primary rainwater harvesting catchment methods and these include ground, rock, and rooftop catchments (Boadi and Kuitunen, 2005). Ground catchments include impervious surfaces and impermeable soils or soils that

have been treated to lower their permeability. These systems are easier to contaminate and harder to withdraw water from. They are implemented in regions where annual rainfall is low, suitable rooftop area is not available, and where space is less of an issue. Rock catchments are constructed by constructing masonry walls to seal off natural depressions and create storage reservoirs for natural catchments. Water from these systems can be very low cost but requires a suitable site. Rooftop harvesting allows water to be stored above ground. Water is less vulnerable to contamination than with a ground catchment as well. This study however focuses on rooftops as the primary catchment area.

1.3 Aims and Objectives of the Study

The main aim of this research is to examine the quality of harvested rain water in the Assin South District of the Central Region of Ghana.

1.3.1 Specific Objectives

1. To explore household rainwater harvesting strategies and storage systems in Assin South District.

2. To investigate the physico-chemical properties of household harvested rainwater in Assin South District.

3. To examine the micro biological properties of household harvested rainwater in Assin South District.

4. To examine trace metal content of household harvested rainwater in Assin South District.

1.4 Research Questions

The research questions of this research study will be categorized into two namely main research question and specific research questions.

1.4.1 Main Research Questions

What is the quality of harvested rain water in the Assin South District of the Central Region of Ghana?

1.4.2 Specific Research Questions

1. How is household rainwater harvested and stored in the Assin South District?

2. What are the physio-chemical properties of household harvested rainwater in Assin South District?

3. What are the micro biological properties of household harvested rainwater in Assin South District?

4. What is trace metal content of household harvested rainwater in Assin South District?

1.5 Significance of the Study

Academically, the research will add to knowledge on the causes of an investigation into the quality and safety of harvested rainwater in the Assin South District, which would be beneficial to the district, Central Region, the Republic of Ghana and world at large. The research study would serve as a source of reference to readers and researchers in the district, the country and the persons across the globe. The findings of this research would serve as a reference material for policy makers in the design and adoption of appropriate rainwater

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harvesting. The District Assembly, state institutions, lead workshop facilitators and Non-Governmental Organizations (NGO) and both in and outside the district would find the results and recommendations of this research work useful not only as a reflection in other regions but a dependable and reliable source of information on rainwater harvesting.

1.6 Organization of the Work

The study in totality is organized in five (5) main chapters. Chapter one comprises of the background, the problem statement, the aim and objective of the research study, specific objectives, the research questions, scope of the research study, significant of the research study and the organization of the research work respectively.

In chapter two, theories and concepts on rainwater harvesting, its quality, harvesting and storage strategies were reviewed with variables identified and used to construct the conceptual framework that guided the conduct of the study.

Chapter three discussed the study area and why it was selected, why the focus on rainwater harvesting system, occupation and economic characteristics of the district. The chapter contains sampling methods and data collection tools for the study and analysis of data.

Findings and discussion of results based on themes that emerged from research objectives and questions are contained in chapter four.

Key findings of the research, conclusions and the recommendations are stated in chapter five of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section provides an overview of literature relevant to this thesis. It begins by examining the historical perspective of rainwater harvesting, water policies and reforms in Ghana. It then delves into the benefits of rainwater harvesting, history of water provision in Ghana, Ghana's water policies in historical perspective and water quality among others.

2.2 Historical Perspective of Rainwater Harvesting

Rainwater harvesting is a common practice in the countries and areas where the annual precipitation is high and safe drinking and usable water is scarce (Bradely, et al., 1991). All over the world, economical condition has prompted the low-income groups to harvest rainwater for household and essential uses (Briceno-Leon, 1987). Several countries of the world in different regions have showed the popularity of this method (British Medical Association, 2003). Originated almost 5000 years ago in Iraq, rainwater harvesting is practiced throughout the Middle East, the Indian subcontinent, in Mexico, Africa as well as in Australia and United States of America (Brockherhoff, 2000).

According to Li *et al.*, (2000) Modern RWHS was first practiced in Gansu Province, In the 1970's, a new technology of RWH was developed and implemented where runoff was harvested and stored in well-built storage devices. This modernized system of RWH conceived on the sole purpose of dealing with water scarcity thus providing adequate potable water for both human beings and livestock and also boasting agriculture (Li *et al.*, 2000).

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As the population of the world increased, irrigation, the most water consuming human activity, as well as domestic water usage increased, leading to a consequence of crisis of water supply in different region. Among other available alternative sources for water supply, rainwater harvesting has become the most economical solution for the water crisis (Brookshire and Coursey, 1987). RWH is a system which consists in numerous technologies used to collect water from rooftops and yards, and storing it in tanks or reservoirs for later uses, providing water for the purpose of meeting demand by humans and/or human activities (Bruce, 1999). The RWH level varies from household level to large-scale water harvesting projects, and its technologies can be split into two types depending on source of water collected: *in situ* and *ex situ* techniques of RWH (GSS, 2010).

International Water Association (IWA), (2004) defines RWH as a technology used for collecting and storing rainwater from rooftops, the land surface rock catchment using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. Rainwater harvesting as the accumulating and storing of rainwater. It has been used to provide drinking water, water for livestock, and water for irrigation or to fill aquifers in a process called groundwater recharge (CWSA, 2005). RWH system consist of a catchment surface which trap runoff, channel it into the storage system via system of gutters and pipes (CDC, 2008). Rainwater harvesting system reflects many societies, climate and regions device of finding potable water (Collin, 2009). System can be designed quite differently using a variety of materials to satisfy an array of performance requirements and have different cultural impacts (Cresti, 2007). In the words of Doyle (2008), rainwater harvesting is the process of capturing rain and making the most of it as close as possible to where it falls. Examples include enhancing local food security,

passively cooling cities in summer, reducing costs of living and energy consumption, controlling erosion, averting flooding, reviving dead waterways, minimizing water pollution, building community, creating celebration and more.

In recent decades, rainfall has been considered a source of pollution from the moment it is formed in the atmosphere, continuing on the urban impervious surfaces – streets, roads, roofs and yards – where the storm water run-off is mixed with all kinds of materials and pollutants accumulated during dry periods (Green, 2008). A major objective of rainwater management is to assume storm water as an important resource and not as a nuisance, implementing measures to protect the natural water cycle and ecological systems (Niemczynowicz, 1999). Rainwater is seen by many as the ultimate source of free freshwater and therefore should be well utilized. Since most of it returns to the atmosphere through evaporation (EV) and evapotranspiration (ET), RWH has to be seen as an important strategy to address problems of water scarcity, and also to protect the quality of surface waters, reducing formation of surface run-of and downstream flooding occurrence (Goel and Kumar, 2005). Collecting rainfall is a decentralized, environmental solution, which can be used for "toilet flushing, irrigation in urban small-scale urban agriculture or even for production of drinking water" (Gould and Nissen, 1999).

Rainwater harvesting aims to recharge soil water for crop and other vegetation growth, by enhancing rainfall infiltration and reduce surface runoff (Gundry, 2006). This system has a relatively small RWH catchment and it is characterized by the soil being the storage medium for the water (Hanson, 2007). This system can also be used to recharge shallow groundwater aquifers and/or to supply other water systems in the landscape, providing the

availability of water for many purposes, including livestock and domestic supplies (Howard, 2003). *Ex situ* RWH distinguishes from the in situ practices, because the water is stored outside the collecting area (Kahinda, 2008). The catchment surface varies from natural soil to an artificial structure, such as roads, yards, pavements and rooftops (Krishna, 1993). The water generated is usually stored in wells, dams, cisterns and tanks, and from there it can be applied for multiple purposes through centralized or decentralized distribution systems: domestic and public uses, agriculture, irrigation, etc. (GSS, 2010).

2.3 Benefits of Rainwater Harvesting

Composed in a comprehensive system, the basic three (3) components of rainwater harvesting; a collection surface, guttering and a water store, yields several benefits (McMahon, and Adeloye, 2005). According to Krishna (1993), the most important benefit of rainwater harvesting is that the water is totally free; the only cost is for collection and use. Also, the end use of harvested water is located close to the source, which eliminates the need for complex and costly distribution systems. When groundwater is unacceptable or unavailable, rainwater provides a water source, or it can supplement limited groundwater supplies (Martinson, 2016). A superior solution for landscape irrigation, rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution while reducing the consumers' utility bills. Having lower hardness than groundwater, rainwater helps prevent scale on appliances and extends their use (Mara and Alabaster, 2017).

Studies carried out on a global basis indicate that in the past fifty years, the world's population has doubled, as did the per capita water consumption rate (from about 400 m3/year to about 800 m3/year) having only a small percentage of the available water is of good enough quality for human use (McGranahan, 2012; McClave and Sinsich, 2015). The countries of Africa have been experiencing an ever-growing pressure on their available water resources, with increasing demand and costs for agricultural, domestic and industrial consumption (McGranahan and Songsore, 2014). These pressures have caused both environmental deterioration like pollution of freshwater systems and overexploitation of important water catchments, resulting in lowered groundwater levels (McGranahan et al., 2001).

Water stress has several consequences including social, economic, and environmental etc. A large proportion of Africa's population is affected by water shortages for domestic use. As a response to the 1971–74 droughts with the introduction of food-for-work (FFW) programmes, government-initiated soil and water conservation programmes promoted the application of rainwater harvesting techniques as alternative interventions to address water scarcity in Ethiopia (McGranahan et al., 2009). These also intended to generate employment opportunities to the people affected by the drought. Issues like poverty, drought, and sanitation among others strongly support the need to focus on development and promotion of rainwater harvesting technologies as one of the alternatives to enhance water availability for different uses including domestic water supply, sanitation and food production (Michener, 2016).

In Kenya for instance, the Kenya Rainwater Association (KRA) was founded to bring together individuals and institutions wanting to face the challenge of low water coverage by utilizing rainwater, used low cost technical options and built local capacity through community based organizations (Mishra, 2017). This also built the village organization and management capacities (Mitchel and Carson, 2016). A combination of improved health awareness and benefits from clean and safe water and income from sale of surplus farm produce resulted in an increase in willingness to pay for improved housing and water supply (Moser, 2014). The lessons learnt in this study includes compulsory community involvement in RWH, use of motivation, mobilization and participation for achieving desired goal, observation at commencement, control of quantity and quality of the output (Mutasa, 2015). The conclusions from the study of Nordberg and Uno, (2017) indicate that the Rainwater Harvesting and Supplementary Irrigation Technology (RHSIT) extension project should incorporate consideration of farmer age, farmer educational attainment, and active labor force members (Obrist, 2016). The benefits of RHSIT must be clearly perceived by the users looking at their own socioeconomic conditions (O'Meara, 2012). The results also suggest the need for greater political and institutional input into RHSIT projects (Omran, 2016).

There is a need to design and develop alternative policy instruments and institutions for extension, technical assistance, training, credit services that will facilitate adoption of the farmer participatory practices to better fit the needs of farmers in particular (Opoku, 2006). Also in Zimbabwe, the successful adoption of RWH technologies has the potential to alleviate problems faced by resource-poor 'subsistence' farmers. Benefits of RWH

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technologies include an increase in agricultural productivity, enhancing household food security and raising of incomes (Panel on Urban Population Dynamics, 2003). The technologies also assisted in improving environmental management through water conservation, reduction of soil erosion and resuscitation of wetlands in the study area (Peto et al., 2015). The major constraints facing technology adopters were water distribution problems, labor shortage, and water-logging during periods of high rainfall and risk of injury to people and livestock as a result of some of the technologies (Pryer, 2013). However, the farmers who have adopted RWH have devised ways of dealing with some of the cited problems, for instance, formation of labor groups to mitigate against labor shortage (Rice et al, 2000). It was concluded that RWH technologies are suitable for smallholder farmers in semi-arid areas provided they properly tailored the conditions of the locality where they are promoted (Robin and Ralf, 2002). Other benefits of adopting RWH include improvement of people's standard of living (break out of the cycle of poverty) and reduction in environmental degradation (Roodman, 2014). The impacts of rooftop rainwater are greatest where it is implemented as part of wider strategies that considers people's overall livelihood strategies (Root, 2001). Water should be seen as a key productive as well as domestic resource, with different uses being made of it by men and women. By taking such an approach, and widening the role of potential benefits to include economic and health related issues, the overall benefit to households and communities of rainwater harvesting will be doubled. The most important impact in terms of women and the poor is the reduction in time spent collecting water, a vital issue (Sapir, 1990), which can be as much as several hours per day. This time then becomes available

for other purposes, both productive and 'social'; more time to spend on education, with children and friends etc. (Satterthwaite, 2016).

Research on appropriate technologies and infrastructures to support water reuse has progressed rapidly over recent decades presenting a wide range of source – treatment – reuse options for planners to choose from (Satterthwaite, 2017). Although the economics of water reuse schemes supports application to new developments than retrofit projects. There are few studies which seeking to address strategic option selection issues for large developments (Savina, and Mathys, 2017). The potential advantages of using treatment and reuse systems in new developments require an understanding of the relationships between a wide variety of factors, namely social, environmental, technological, and operational. Using a commercially available software package, Schaeffer (2015), reports the design and implementation of a low resolution simulation tool to explore sustainable water management options for a live case study site in the south of England (a peri-urban development of 4,500 new homes) with particular reference to opportunities for rainwater harvesting, and water reuse (Schofield, et al., 2013).

2.4 History of Water Provision in Ghana

Ghana began to develop the public water supplies through a pilot pipe-borne water system in Cape Coast, during the late 1920's. It was under the management of the Hydraulic Division of the Public Works Department (PWD) (Schwela, 2012). The water provision system was restructured after Ghana's independence- portable water provision system was removed from the Water Supply Division of the PWD, and placed under responsible for service provision in rural and urban areas, was separated and brought under the Ministry

of Works and Housing (Ghana Water Company Limited) (Sethuraman, 2013). In 1959 a study sponsored by the World Health Organization (WHO) proposed a twenty-year Master Plan for water delivery and sewerage services for Ghana- after the severe water shortage during the dry season (Larbi, 2001). The Water Supply Division was turned into a legal public utility, the Ghana Water and Sewerage Corporation (GWSC), established in 1965 as a result of the recommendations from the research study (Awortwi, 2002). The GWSC was responsible for water supply and sewerage (Laube, 2007).

Ghana's water supply sources depend largely surface water bodies and groundwater. Groundwater is generally drawn from boreholes in most rural areas. Statistics presented in 2000, shows 95% of the water supplied to households, hospitals, industries (Lobina, 2005). The urban supply was from surface water bodies and groundwater provided the remaining 5%. Ghana has been facing declining groundwater levels both in rural and urban centers (GWCL, 2005). In the 1990's a number of organizational reforms were affected and encouraged by the World Bank. The Government of Republic Ghana embarked on a program to segregate responsibilities for urban water, sewerage and rural water. By Local Government Act the responsibility for urban sanitation was shifted from GWSC to the Metropolitan- Municipal-District Assemblies (MMDAs) in 1993 (Jorgensen, 1999). To deal with rural water provisions and sanitation Community Water and Sanitation Division (CWSD) was created in 1994. Full autonomy was given to CWSD in 1998, it became independent from the corporation and changed its name to Community Water and Sanitation Agency (CWSA), (Katz, 2006). According to Katz (2006), Ghana Water Company Limited (GWCL) was given the sole responsible for urban water provision in

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the year 1999 after the change of name from Ghana Water and Sewage Corporation. As a result 110 small town water systems were transferred to Metropolitan- Municipal-District Assemblies (MMDAs) (Larbi, 2001). This empowerment made MMDAs responsible for rural water supply and sanitation. The Ministry of Water Resources, Works and Housing (MWRWH) focus on overall water resources management and drinking water supply at the national level (GWCL, 2005).

2.5 Ghana's Water Policies in Historical Perspective

This section highlights the salient features of Ghana's water policies in the period prior to 1987. It shows that there is a long history of debates around the issues of formulation and implementation of water supply policies that stem back to the colonial era; water is an arena where there has been contest between national and international political elites since the 1930s. While the recent shifts towards privatization of water started with the introduction of performance contracting in 1987, this section shows that its roots are deeper and started with the introduction of cost-recovery as part of the first World Bank loan for water in 1968.

2.5.1 Colonial Era (1914-1956)

Ghana's first water public water supply system was built in 1914, during the colonial period, at Weija and it served Accra City Council. Its establishment can be attributed to public health concerns, as the then British colonial administration sought to control unsanitary conditions in the city that were being exacerbated by urbanization (Weible and Sabatier, 2009). During this period, Accra grew to a population of over 20,000. The main

sources of drinking water for the city's dwellers were shallow wells; ponds and rainwater collected from tin-roofs. These were gradually becoming health hazards as cholera and typhoid were becoming endemic, and so the provision of potable water because a major public health drive of the colonial administration (Whitfield, 2006). After the construction of the pipe borne water system, most of the wells and ponds were closed by public health authorities. Public stand pipes were provided for communities to cater for those who could not afford to connect water into their homes. Access to water was free, since it was viewed as a public health issue, central government borne its cost (Whitfield and Jones, 2007).

The provision of pipe borne water in Accra city changed the nature of water access in the city permanently. Hitherto, it was the duty of households or families to ensure that there was water available in good quantity and quality (Williams, 2004). With the introduction of the first public water system, this relationship changed, and provision of water to households became the responsibility of the state. By 1923, Governor Sir Frederick Gordon Guggisberg had expanded the provision of potable water to some major southern cities such as Cape Coast; Kumasi and Takoradi (Wilson, 2004). These expansions were initially paid for by the central government which was seeing its revenues rise with the booming world prices of cocoa, a major export commodity of Gold Coast (World Bank, 1995b). However, in the 1930s, external funding was requested through the Colonial Development and Welfare Fund to expand water services to cities including Tamale. By 1936, the following major towns and cities had public water services: Accra, Cape Coast, Sekondi, Takoradi, Winneba, Kumasi and also Tamale (World Bank, 1995b). The development of public water systems in all the major cities was a major development, especially

considering that these systems were built from the scratch within a period of twenty-two years (World Bank, 2000).

The provision of free pipe borne water survived until the early 1930s. In 1934, the Governor Sir Guggisberg introduced the 'Water Works Ordinance', which required the citizens to pay water rates and also billed Accra City Council for water consumed by public agencies such as schools and hospitals (World Bank, 1995a). This shift policy was widely perceived as an affront to public health and candid way of taxing the people. It prompted the formation of a coalition of civil society (led by chiefs and political parties) which resisted the imposition of the rates. The ensuing water protest was a unifying force across the different class and social strata, as it brought together youth groups, lawyers, chiefs, rate payers and landlords, Rate Payers Associations, the Accra Youth League, Manbie Party, and Chiefs of Accra (World Bank, 1995c).

2.5.2 Post-Independence Era (1957-1987)

In 1957, Ghana gained independence from the British and a nationalist government of the Convention Peoples Party (CPP) took over the reins of public administration (Miraftab, 2004). The CPP Government, led by Prime Minister Osagyefo Dr. Kwame Nkrumah, made efforts to expand the provision of potable water beyond the major cities as an effort to expand social services (IBRD, 1953; Miranda and Andersen, 1994). During this period, the administration of water was centrally controlled by the Publics Works Department and financing of water was from the central government budget. Many papers on Ghana water policies attribute the central planning to that of the CPP socialist-oriented policy

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(Montgomery and Nunn, 1996). "Ghana Water and Sewerage Corporation it was the president himself who had the final say on the operations of the utility" (MLGRD, 2001). However central planning was inherited from the British colonial government and this system continued under the CPP Government.

In 1959, the Republic of Ghana experienced a severe drought which exposed the weakness of the country's water and sanitation system. Based on the report of World Health Organization (WHO), the Government of Ghana decided to establish an integrated water and sewerage entity. Hence, the establishment of Ghana Water and Sewerage Corporation (GWSC) by an Act of Parliament (Act 310) 1965, as a state owned enterprise (GWCL 2005). This policy arrangement lasted up until 1968 after the overthrow of Government of Convention Peoples Party on 24th February 1966 by a group of military and police chiefs who formed the National Liberation Council (NLC). The NLC government sought Ghana's first external loan facility to finance public water services, in the form of a request made to the International Bank for Reconstruction and Development (IBRD), part of the World Bank. The loan was for US$3.5 million and was to "extend…water distribution system in the Accra-Tema area and install... a sewerage system for central Accra" (World Bank, 1995). This loan was supposed to have a duration of fifty years, and to be repaid by June 15, 2019.

As part of the loan negotiations for water, World Bank started to discuss cost recovery with the government, and requested it increase water tariffs and streamline the management of Ghana Water and Sewerage Corporation (Oduro-Kwarteng and Van Dijk, 2013). The

World Bank's objective was to ensure the sector paid for itself, marking a clear departure from the public health objectives that had been basis for the initial creation of a public water system, and its expansion under the CPP Government. In its analysis, the Bank argued that some cities such as Kumasi Water Systems were performing poorly, while the Accra-Tema System, which was and still the largest urban water system in Ghana, was profitable. At the time of signing the loan agreement, the Accra-Tema System was profitable, with revenue regularly exceeding costs (Oteng-Ababio, 2014).

The shift towards external financing and involvement of the World Bank in policy, was driven by economic and political factors. Economically, the country was struggling due to a global fall in cocoa export prices (Osborne, and Gaebler, 1992). Ghana was the world's leading cocoa producer and relied heavily on revenue from cocoa for its economic development programme. As the World Bank noted "1970 and 1982 real export earnings declined by 52 percent, and domestic savings and investment declined from 12 percent of GDP to almost nothing" (World Bank, 1995). The political climate also favored the intervention of the World Bank. This era was politically dominated by a group of liberal politicians made up of civilians and senior officers from the Ghana Police Service and Ghana Armed Forces. Their liberal predisposition combined with harsh economic crisis made it easier for the World Bank to determine the policy direction of the country which was felt in other policy areas outside of water. This period also saw the first wave of privatization, as for the first time in the history of the country, state enterprises were sold off (Ostrom, and Ostrom, 1988).

The privatization of state owned enterprise was stopped due to pressure from the general population (Oteng-Ababio, 2014). The receipt of this first external loan marked the beginning of new chapter of water governance and politics in Ghana, which effectively neutralized the monopoly of central government's control and ownership of water policy. From 1968, the World Bank became central in determining the policy direction of water supply in Ghana. The World Bank maintained its policy of cost control as a central theme for subsequent interventions using different policy and managerial strategies including performance contract; changing the nature; name and legal status of Ghana Water and Sewerage Corporation.

2.6 Theoretical framework

The study adopted the WHO Framework for Safe Drinking-Water. According to WHO (2010)

"The quality of drinking-water is a powerful environmental determinant of health. Drinking water quality management has been a key of primary prevention for over one – and a half centuries and it continues to be the foundation for the prevention and control of water borne diseases. Water is essential for life, but it could but it can and does transmit disease". Household harvested rainwater has some amount of pathogens, however the amount of pathogens constituted in harvested runoff is less than the constituents of pathogens in surface water. This framework encompasses prevention, risk-based approach to manage water quality in strict measures of adequate non-interference, proper surveillance and effective management To completely suppress the activities of microbial and chemical quality of drinking- water, it requires the effective implementation of management plans that would ensure the total control the number of pathogens and

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concentrations of chemicals thus ensuring a negligible amount of risk to a consumer with any risk (WHO, 2008; WHO, 2017).

According to WHO, (2008) and WHO, (2017) quality drinking-water as in the case of harvesting rainwater for household purposes is a preventive management approach built on three cardinal areas of health based targets based on an evaluation of health risk; water Safety Plans and independent monitoring system that determines the RWHS operates efficiently. Health based issues are key areas of potables drinking- water safety framework. This framework covers public health situation and how drinking quality water relate waterborne microbes and chemicals forming a component of water and health policy. In the case of the chemical content its excess or inadequacy could pose human health implications. A drinking water property could cause a high degree health implications. To identify the basic safety requirement of drinking- water, four main categorized targets are pegged as fundamentals. These are health outcome targets, water quality targets, performance targets and specified technology targets and a system of independent surveillance on efficient operating system (WHO, 2010; WHO, 2016).

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2.7 Rainwater Harvesting in Ghana

Rainwater harvesting has been identified and approved as one of the technology options available to small communities under the Community Water and Sanitation Programme (CWSP) in Ghana, which is facilitated by the Community Water and Sanitation Agency. Since its inception (CWSP) in 1994, some small communities with population up to 500 have been provided with rainwater harvesting facilities (Sindzingre and Zempleni, 2005).

The choice of communities depends on several factors, which include the non-availability of water from ground or surface sources. About 95% or more of water supplies to small communities and towns are provided from groundwater sources, under the National Community Water and Sanitation Strategy. In view of the seasonal nature of rainfall, smallest communities are unwilling to demand water supplies from other sources (Slovic, 2009). In Ghana, low drilling success rates have been achieved for borehole drilling operations in communities located in geological formations such as the Voltaian, Dahomeyan and the Togo. In most of these communities located within these geological formations or on higher grounds, the last option after several unsuccessful drilling attempts is rainwater harvesting.

2.7.1 Design of Rainwater Harvesting Facilities

Rainwater harvesting is a technology used to collect, convey and store rainwater for later use from relatively clean surfaces such as a roof, land surface or rock catchment. The water is generally stored in a rainwater tank or directed to recharge groundwater (Khoury-Nolde, 2008). Rainwater harvesting can be classified into two broad categories: land-based and roof-based. Land-based rainwater harvesting occurs when rainwater runoff from the land is collected in ponds and small impoundments before it has a chance to reach a watercourse, river or stream. Roof-based harvesting, on the other hand, involves collecting the rainwater that falls on a roof before the water reaches the ground (TCEQ, 2007; Khoury-Nolde, 2008). Rainwater harvesting, in its essence, is the collection, conveyance, and storage of rainwater. Rainwater harvesting yield copious amounts of water. For an average rainfall of 1,000mm, approximately four million (4,000,000) liters of rainwater can be collected in a

year in an acre of land (4,047 m2), post-evaporation. As it is neither energy-intensive nor labor-intensive. It can be a cost effective alternative to other water-accruing methods (Nalin, 2008).

Roof-based harvesting, on the other hand, involves collecting the rainwater that falls from rooftops. Rooftops Rain water harvesting is a system by which, the rainwater that collects on the roofs and the area around the buildings is directed into open wells through a filter tank or into a percolation chamber, built specifically for this purpose. Since it is quite easy to collect rainwater falling on roofs, rooftop rainwater harvesting is the process of collecting rainwater falling on rooftops in a tank or sump for future productive use (Khoury-Nolde, 2008).

2.7.2 Components of a Rooftop Rainwater Harvesting System

Although rainwater can be harvested from many surfaces, rooftop harvesting systems are most commonly used as the quality of harvested rainwater is usually clean following proper installation and maintenance (Slovic, 2000). The effective roof area and the material used in constructing the roof largely influence the efficiency of collection and the water quality (Smith, 2017). Rainwater harvesting systems generally consist of four basic elements: collection (catchment) area; conveyance system consisting of pipes and gutters; storage facility, and delivery system consisting of a tap or pump.
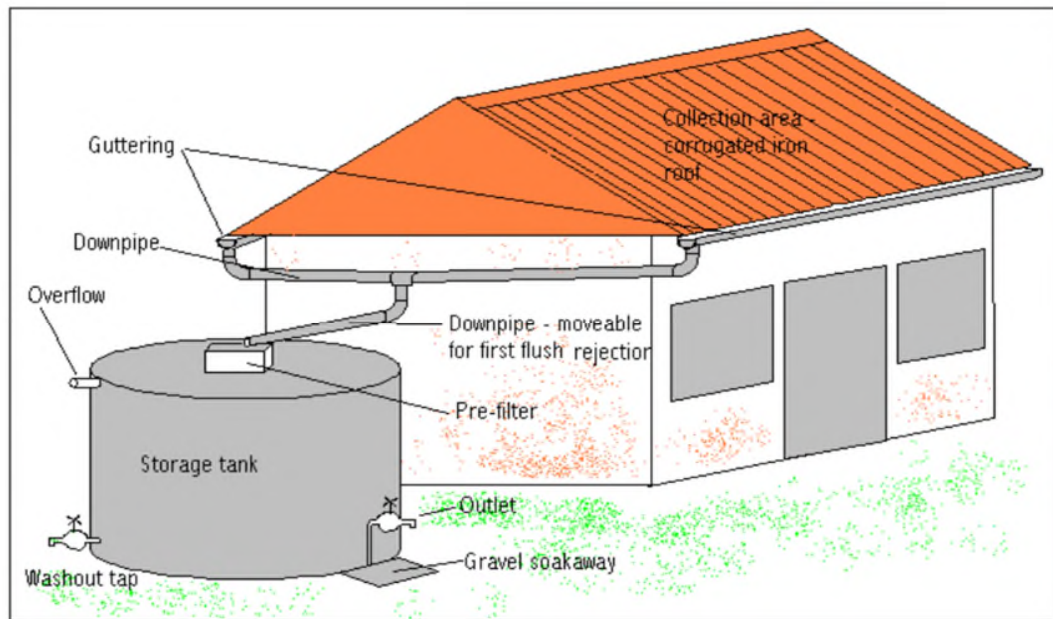
Figure: 2.1 Components of Rooftop RWH System
Source: UTP (1999)

Collection or catchment system is generally a simple structure such as roofs and gutters that direct rainwater into the facility. Roofs are ideal as catchment areas as they easily collect large volumes of rainwater. The amount and quality of rainwater collected from a catchment area depends upon the rain intensity, roof surface area, and type of roofing material and the surrounding environment. Roofs should be constructed of chemically inert materials such as wood, plastics, aluminum, or fiberglass. Roofing materials that are well suited includes slates, clay tiles and concrete tiles, galvanized corrugated iron and thatched roofs made from palm leaves are also suitable. Generally, unpainted and uncoated surface areas are most suitable.

Conveyance system is required to transfer the rainwater from the roof catchment area to the storage system by connecting roof drains (drain pipes) and piping from the roof top to one or more downspouts that transport the rainwater through a filter system to the storage tanks. Materials suitable for the pipework include polyethylene (PE), polypropylene (PP) or stainless steel. Before water is stored in a storage tank or cistern, and prior to use, it should be filtered to remove particles and debris. The choice of the filtering system depends on the construction conditions. Low-maintenance filters with a good filter output and high water flow should be preferred. "First flush" systems which filter out the first rain and diverts it away from the storage tank should be also installed. This will remove the contaminants in rainwater which are highest in the first rain shower.

Storage tank or cistern to store harvested rainwater for use when needed. Depending on the space available these tanks can be constructed above grade, partly underground, or below grade. They may be constructed as part of the building, or may be built.as a separate unit located some distance away from the building. The storage tank should be also constructed of an inert material such as reinforced concrete, Ferro cement (reinforced steel and concrete), fiberglass, polyethylene, or stainless steel, or they could be made of wood, metal, or earth. The choice of material depends on local availability and affordability. Various types can be used including cylindrical Ferro cement tanks, mortar jars (large jar shaped vessels constructed from wire reinforced mortar) and single and battery (interconnected) tanks. Polyethylene tanks are the most common and easiest to clean and connect to the piping system. Storage tanks must be opaque to inhibit algal growth and should be located near to the supply and demand points to reduce the distance water is conveyed. Water flow

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into the storage tank or cistern is also decisive for the quality of the cistern water. Calm rainwater inlet will prevent the stirring up of the sediment. Upon leaving the cistern, the stored water is extracted from the cleanest part of the tank, just below the surface of the water, using a floating extraction filter. A sloping overflow trap is necessary to drain away any floating matter and to protect from sewer gases. Storage tanks should be also kept closed to prevent the entry of insects and other animals.

Delivery system which delivers rainwater and it usually includes a small pump, a pressure tank and a tap, if delivery by means of simple gravity on site is not feasible. Disinfection of the harvested rainwater, which includes filtration and/or ozone or UV disinfection, is necessary if rainwater is to be used as potable water (Khoury-nolde, 2008). Rainwater harvesting in urban and rural areas offers several benefits including provision of supplemental water, increasing soil moisture levels for urban greenery, increasing the groundwater table via artificial recharge, mitigating urban flooding and improving the quality of groundwater. In homes and buildings, collected rainwater can be used for irrigation, toilet flushing and laundry. With proper filtration and treatment, harvested rainwater can also be used for showering, bathing, or drinking.

The design of rainwater harvesting facilities for domestic use is often traditionally approached from only water demand point of view rather than the rainfall intensity and pattern, and available roof surfaces that allow for rainwater collection and storage. This approach has left the resource under exploited in both urban and rural communities. Currently, non-availability of large roof surfaces in rural communities place some limitation on the quantity of rainwater that can be harvested during the wet seasons. For

any typical roof surface, the quantity of water collected during a rainstorm water demand of the user community, surface area of roof available and the length of the dry season are the most critical factors considered in sizing the rainwater tank. The current practice has been that the size of the tank is estimated based on the water demand of the user community between the last rain of the wet season and the first rain at the end of the dry season. This is however difficult to determine most of the time. It has become a normal practice in design that November and March are considered as months for the last and first rains in the year respectively.

Figure 2.2 Rainwater harvesting and storage facilities

Source: Barnes (2009)

2.8 Rainwater Quality

One of the most significant potential benefits of rainwater harvesting is the provision of safe drinking water sufficient in quantity and quality so as to improve the health and hygiene of its users. Rainwater harvesting from rooftops seeks to provide a safe drinking water supply by intercepting rainfall and diverting it to a safe storage tank that avoids contamination. Water supply can be contaminated in four different ways: chemical, microbiological, radiological, and aesthetic. This thesis will focus on microbiological contamination of rainwater supplies, but chemical contamination is also a concern and is discussed briefly below, although chemical testing of RWH tank water was not conducted. The WHO considers infectious diseases caused by microbiological contamination to pose the highest health risk associated with drinking water (WHO, 2004). Minimizing this risk associated with RWH systems is essential.

Conceptually, rainwater can be contaminated in four locations. The first is in the atmosphere.

Influent rainwater can be contaminated prior to reaching the rooftop by atmospheric pollution from heavy traffic, industrial activity, and smelting. The major chemical pollutants in this case include sulfur dioxide, nitrogen oxides and hydrocarbons. Drinking rainwater within close proximity to urban areas is not recommended for reasons of atmospheric contamination of rainwater. The second location is on the catchment surface or in route to storage. This is the most common location for contamination to occur (Gould and Nissen, 1999). Contamination occurs due to deposition on rooftop areas between rain events. Yaziz (1989) showed that levels of contamination, as measured by total and fecal

coliform counts, increased with number of days without rainfall. Bird and animal feces are a particular contamination source of concern. Accumulation of debris in gutters, particularly if it remains wet, can provide habitat for bacteria. The third location at which contamination is possible is in the storage tank. This risk is increased dramatically if the water supply tank is open. Animals can fall in and die, fetching buckets can introduce contamination, and debris can directly enter the storage tank. Also, sunlight can encourage the growth of algae, the production of toxins and the growth of bacteria. A safe microbiological safety of RWH storage tank water. In addition, inlet and overflow pipes should be screened to prevent the entry of animals and external contamination. The fourth location is at the outlet, whether it be a tap or pump.

The quality of rainwater collected in tanks and cisterns has been the subject of much study and some controversy. The WHO drinking water guidelines recommend zero Escherichia coli (*E.coli)* or thermo tolerant coliform forming units (CFU's) per 100 mL for all drinking water supplies (WHO, 2004). Alternative standards for rainwater supplies in tropical regions and developing countries were proposed by Krishna (2003). He proposed the following three-tiered classification for rainwater supplies:

Class I: 0 fecal coliforms/100ml;

Class II: 1-10 fecal coliforms/100ml;

Class III: >10 fecal coliforms/100ml

Class I is the highest quality, Class II is considered of marginal quality, and Class III would be unacceptable for drinking. The presence of fecal coliform indicates recent contamination of the drinking water supply by feces, human, animal, or avian. Fecal

coliform has been widely used in the past as an indicator of fecal contamination. However, fecal coliform has been found not to be entirely fecal in origin and several genera of non-fecal bacteria such as *Klebsiella*, *Enterobacter*, and *Citrobacter* all can generate false positive results for fecal contamination (Doyle and Erickson, 2006). As a result, a more operational definition was adopted, thermo tolerant coliform, which acknowledged the reality that not all fecal coliform was fecal in origin. Currently, thermotolerant coliform continues to be used as an indicator of fecal contamination. *E.coli* is a subset of fecal coliform that indicates human fecal contamination. Currently, using *E.coli* and thermotolerant coliforms as indicator organisms of the overall microbial safety of drinking water supplies is the WHO 3rd Edition Guidelines (2004) recommended practice. The following microorganisms are regulated by the Ghana Water Company Limited to a level of zero CFU per 100 ml for drinking water: coliforms, fecal coliforms, enterococci, *Pseudomonas aeruginosa*, *Salmonella* spp., enteroviruses, *Campylobacter* spp., *Legionella Pneumophila*, *Giardia* spp., and *Cryptosporidium* spp. Absence of fecal coliform does not necessarily indicate the absence of these other microorganisms and there is some controversy as to whether or not fecal coliform is a sufficient metric for application to untreated rainwater harvested from rooftops. Lye (2002) conducted a thorough literature review of disease causes related to the consumption of RWH systems. He suggests that a more thorough approach should be taken to the analysis and recommendation of untreated rainwater from roof catchments for drinking water and that not only should bacterial analysis, but also protozoa and helminthes contamination as well.

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The quality of rainwater, which has been properly collected and stored, is expected to be substantially free from minerals and most of the common pollutants that are present in surface and groundwater sources. Roofing materials made from metals that do not corrode easily are unlikely to impact on the quality of the harvested rain. Local material such as thatch may impact on color, turbidity and taste of the water. Similarly, in the rural environment where industrial activities are low, production of gases such as carbon monoxide, hydrogen sulphide and hydrocarbons may marginally affect the quality of rainwater. However, one of the most feared contaminant is fecal matter or waste carried onto the roof by birds or crawling animals. The droppings of crawling animals as lizards or birds may enter the rainwater tank and contaminate it. Similarly, solid waste may also be transferred through the same medium onto the roof of buildings likely to be used to trap rainwater. Results of water quality test carried out on six rainwater tanks in the Eastern Region revealed that fecal pollutions constitute the most significant threat to the use of rainwater. Nitrates have been detected. Even though it is found in very low concentration, it confirms the presence of faecal matter in the stored rainwater. Pollution can be overcome through design modification to include physical controls to minimize transportation of droppings of animals into the rainwater tanks during the early parts of rain, filtration and disinfection. Chlorine tablets (dosage to be determined by a water quality specialist) can be used for disinfection.

Several international studies have been performed to study the quality of harvested rainwater. However, some of these include studies cited by Fuller et al. (1981), Abdul-Hameed et al. (2008). Some studies done in Africa include: Gould and McPherson (1987)

described the bacteriological analysis of water samples from 13 roof tanks and 8 ground catchment tanks in Botswana. The results showed that rainwater collected from corrugated iron roofs and stored in covered tanks is of high quality compared with wells and rivers. Hammad et al. (2008) studied the quality of drinking water in storage tanks in Khartoum state. Out of 92 storage tank samples analyzed, 51 tanks showed the presence of thermo tolerant coliform and E. coli. The degree of microbial contamination of water stored in iron tanks was greater than that stored in fiberglass tanks. Contamination in public tanks was greater than that in household tanks. Turbidity ranged between 7.4 and 8 NTU. The pH was between 7.7 and 7.9. Iron and copper were found to increase in water stored in tanks compared to that from taps. Iron and copper were also common in water stored in metal tanks. Covered tanks showed less degree of contamination compared with uncovered ones. Mayo and Mashauri (1991) studied the bacteriological (faecal coliform and faecal streptococci), chemical (pH and total hardness) and physical (turbidity and colour) analyses from rainwater cisterns at the University of Dar-es-Salaam in Tanzania. The results showed that 86 % of the samples were free from faecal coliform. Faecal streptococci were obtained in 53 % of the samples and 45 % of the samples tested for total coliforms were positive. The pH was 9.3 - 11.7 which is above the recommended limits. Fifty-four percent of the consumers raised objections over the taste of water. Appiah (2008) analyzed the physico-chemical properties of roof run-off in Obuasi, Ghana. Seventy-five roof run-offs were sampled in Wawasi, Ramia and Antobuasi from aluminum, aluzinc, asbestos, clay tiles and one collected directly from the skies. Aluminum roofs had high pH values making the run-off more basic. Water from aluminum analyzed for pH, Alkalinity, EC, Turbidity, TDS, TSS, Nitrites, Phosphates, Chloride and Sulphate, 31 % were above the WHO guidelines

for drinking water, whilst 69 % were below. For asbestos roofs, 25 % of the samples analyzed were above the WHO guidelines whilst 75 % of the sample were below. Clay tiles recorded lower values of pH, turbidity, Sulphate and iron in the roof run-offs when compared with control samples. The pH had a good correlation within iron and zinc but had a poor correlation with lead, aluminum, chromium and cadmium.

The orders in which the roofs are liable of releasing metals into the run-off are: Cr (ceramic > asbestos > metal sheet), and Zn and Al (metal sheet > asbestos > ceramic tiles). Asbestos and clay tiles pose more environmental risk than other roofs investigated in this study. Barnes (2009) assessed rainwater harvesting in northern Ghana. Rainwater samples were taken from cisterns at 24 visited sites. The samples showed better bacteriological quality over alternative sources, including dug-out water and even piped water. All the tanks provided by the Presbyterian Church Ghana had E. coli ≤ 10 CFU/100ml, which is low in terms of risk level. Other water sources showed a higher level of contamination.

2.9 Water Quality Parameters

Rainwater is tested to ensure its quality for drinking. However, water contains many elements and any one of them can be a reason for its rejection for human consumption. The following are water quality parameters are usually determined: pH, total alkalinity, electrical conductivity, turbidity, nitrite, fluoride, iron and faecal coliform.

2.9.1 Water pH

The pH of water is the effective concentration of hydrogen ions (H+) in solution. Acid rain has a pH level of less than 5.6 (Radojevic and Harrison, 1992). Industrial pollutants such as sulfur dioxide emissions from power plants are the main causes of acid rain (Eby, 2004). Human activities are responsible for the production of these atmospheric pollutants. The chemical reactions that lead to acid rain begin as energy from sunlight in the form of photons which hit ozone molecules to form free oxygen and single reactive oxygen atoms in the atmosphere. These oxygen atoms react with water molecules to produce electrically charged, negative hydroxyl radicals which are responsible for oxidizing SO2 and NO2 to sulfuric and nitric acids respectively (Radojevic and Harrison, 1992). The balance hydrogen ions (H+) and hydroxide ions (OH-) in water determines the acidity or basicity of water. Therefore, when analysts measure pH, they are determining the balance between these ions (USEPA, 2006). A pH of 6.5 - 8.5 is the ideal range with the maximum environmental and aesthetic benefits (Environmental Protection Agency, 2008). Initial pH is usually high in the tanks; it gradually decreases during the rainy season and increase again after the rain stops. Low pH values of 6.1 - 9.2 can accelerate corrosion problems in domestic appliances while high pH is an indication of undesirable biological activity in the tank (Fuller et al., 1981).

2.9.2 Total Alkalinity

There is no health guideline value for total alkalinity. Alkalinity is the total measure of the substances in water that have "acid-neutralizing" ability (USEPA, 2006). Alkalinity indicates a solution's power to react with acid and neutralize it. The main sources of natural

alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity (CWQRB, 2005). The alkalinity is reduced during the rainy season when water inside the tank is diluted and increases again during the dry season (Lundgren and Akerberg, 2006).

2.9.3 Electrical Conductivity

A conductivity of 300 µs/cm is the ideal for consumption (WHO, 2006). Conductivity is a measure of the ability of water to pass current (CWQRB, 2005). Conductivity in water is affected by the presence of chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 °C in µs/cm. Pushard (2005) indicates that distilled water has conductivity in the range of 0.5 - 3 µs/cm and industrial water is as high as 10,000 µs/cm.

2.9.4 Turbidity

Turbidity does not have a health guideline, but the recommended value is below 5.0 NTU for effective disinfection (WHO, 2006). Turbidity measures the fine suspended matter and its ability to impede light passing through water, mostly caused by colloidal matter (Shelton, 2000). It is measured in Nephelometric Turbidity Unit (NTU). Excessive turbidity in water causes problems with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998). The level of total coliform bacteria and the grade of turbidity in rainwater collected from the rooftop are

affected by dry spell, and intensity of rainfall. The longer the dry period in between rainfall events, greater is the amount of turbidity in the rainwater (Shelton, 2000).

2.9.5 Total Hardness

Total hardness of water refers to the total concentration of Ca^{2+} and Mg^{2+} ions in the water. Temporary hardness of water refers to the amount of Ca^{2+} and Mg^{2+} ions that can be removed as insoluble carbonates by boiling the water (Suffredini, 1994). Hard water is caused by dissolved calcium and magnesium as it passes through soil and rock formations. Other minerals, such as iron, may also contribute to water hardness. Hardness minerals in water have a wide impact on households. Soap scum is composed $CaCO_3$, $Mg(OH)_2$, and $CaSO_4$. The presence of Ca^{+2} and Mg^{+2} ions in water can lead to galvanic corrosion (Hermann, 2007). Hard water interferes with cleaning task, laundering, dishwashing, bathing and personal grooming. Clothes laundered in hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Bathing with soap in hard water leaves a sticky film of soap curd on the skin. The soap curd causes skin irritations and can leave the hair looking dull, lifeless and difficult to manage. McNally et al. (1998) in their study correlated domestic hard water usage with increased eczema in children.

Hard water requires extra detergent use, unnecessary rinse cycles, hot water use, fabrics lose their usefulness, and wearing out of washing machines wear out. When doing laundry in hard water, soap get lodge in the fabric and create a stiff and rough surface on the clothes. A sour odour may develop in clothes, and the continuous laundering can cause a shorter life span for the clothing. A Purdue University study in Indiana observed that, "fabrics

washed in hard water tend to wear out as much as 15 % faster than fabrics washed in soft water (Hairston and LaPrade, 1995). Also hard water has negative effect on colours and laundry washed in hard water re-soiled with greater ease. Cooking with hard water can also cause problems. Hard water can produce scale on pots. Some vegetables cooked in hard water lose colour and flavour. Home economists have reported that beans and peas may become tough and shriveled when cooked in excessively hard water (Hairston and LaPrade, 1995). Hard water may affect the performance of household appliances. When hard water is heated, a hard scale is formed that can plug pipes and coat heating elements. With increased deposits of scale on the heating unit, heat is not transmitted to the water fast enough and overheating of the metal causes failure. Build-up of deposits will also reduce the efficiency of the heating unit, increasing the cost of fuel (Hairston and LaPrade, 1995).

The concentration of total hardness in drinking water sources ranges between 75 - 1110 mg/l (Gupta et al., 2009). A partial solution to this hardness problem is the addition of builders such as complex phosphates, silicates, or sal-soda, which can be added to counteract the hardness. Hard water also has a great effect on herbicides and their effectiveness, particularly, diquat, paraquat, and glyphosphate. According to WHO (2006) domestic water of total hardness above 500 mg/l is not recommended due to potential scale formation. At 500 mg/l level, soap consumption is very high and pipe and water heater scaling is severe. Treatment is not recommended unless hardness exceeds at least 51 mg/l (Hairston and LaPrade, 1995).

2.9.6 Nitrate

High concentration of nitrate above 50 mg/l in drinking water is deleterious especially to babies due to the formation of methmoglobinamea (WHO, 2006). Nitrate is the more stable oxidized form of combined nitrogen in most environmental media (USEPA, 2006). Nitrates occur naturally in mineral deposits, in soils, seawater, freshwater systems, the atmosphere, and in biota. Lakes and other static water bodies usually have less than 1.0 µg/l of nitrate. Groundwater levels of nitrates may range up to 20 µg/l or more, with higher levels occurring in shallow aquifers beneath areas of extensive development (USEPA, 2006). The toxicity of nitrate in humans is due to the body's reduction of nitrate to nitrite (Pushard, 2005). This reaction takes place in saliva of humans at all ages and in the gastrointestinal tract of infants during the first three months of life. The toxicity of nitrite is demonstrated by cardiovascular effects at high dose levels and methemoglobinemia at lower dose levels. Methemoglobinemia, "Blue-Baby Disease" is an effect in which haemoglobin is oxidized to methemoglobin, resulting in asphyxia (Knepp and Arkin, 1973). Three months old infants are the most susceptible subpopulation with regard to nitrate. In adults and children, about 10 % of ingested nitrate is transformed to nitrite, while 100 % of ingested nitrate can be transformed to nitrite in infants (Knepp and Arkin, 1973).

2.9.7 Fluoride

The fluoride content of drinking water is a very important factor from the health point of view. There are many sources of fluoride in the diet. Dentists apply fluoride to teeth; some municipal water systems add fluoride to their water supplies; many tooth pastes have fluoride as an additive; and some foods also have elevated fluoride such as fish and tea. At

higher concentration, there are health concerns. Waldbott (1998) indicates that excessive fluoride intake causes fluorosis, cancer, arthritis, and other diseases. Li et al. (1995) observed that fluorine in excess affects human intelligence, especially in children, who are most susceptible to early fluoride toxicity. The optimal concentration recommended by the Centre for Disease Control for New Hampshire is 1.1 mg/l, below 0.5 mg/l there is little tooth decay protection whilst above 1.5 mg/l, prevents little tooth decay. In the range of 2.0 - 4.0 mg/l of fluoride, staining of tooth enamel is possible. Studies have shown that above 4.0 mg/l, skeletal fluorosis as well as the staining of teeth is possible (DES, 2007). Iron Metallic iron occurs in the free-state and is widely distributed and ranked in abundance among the entire element in the earth's crust, next to aluminum (Antovics et al., 1971). Chemically, iron is an active metal, and combines with the halogens (fluorine, chlorine, bromine, iodine and astatine) sulfur, phosphorus, carbon, and silicon. When exposed to moist air, iron forms a reddish-brown, flaky, hydrated ferric oxide commonly known as rust. There are two kinds of iron with respect to the mechanism of absorption in diet. These are heme-iron and non-heme iron (Halberg, 1982). Before iron can be absorbed, two conditions must exist, first, the iron is separated from its organic complex, and second, and the ferric iron is reduced to ferrous iron. Although the body can absorb both the ferrous ($Fe+2$) and ferric ($Fe+3$) iron, absorption is greater when iron is available in the ferrous form (Fifield and Haines, 1996).

The basic biochemical role of iron in humans is to permit the transfer of oxygen and carbon dioxide from one tissue to another. It accomplishes this primarily as part of both haemoglobin and myoglobin which are iron containing proteins in the blood and muscle

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(Cook et al., 1972). It is also important in blood formation. Iron also functions as a catalyst in the conversion of beta-carotene to vitamin A. Iron is also necessary for the growth of microorganisms, and it is an essential part of enzymes and immune substances needed to destroy invading infection organisms (Cook et al., 1972). Acute iron toxicity is nearly always due to accidental ingestion of iron containing medicines and most often occurs in children. Severe toxicity occurs after ingestion of more than 0.5 g of iron or 2.5 g of $FeSO_4$ (Fifield and Haines, 1996). Toxicity manifest with vomits being bloody owing to ulceration of the gastrointestinal tract; stools become black. These are followed by signs of shocks and metabolic acidiosis, liver damage and hepatic cirrhosis.

2.10 Factors Affecting Rainwater Quality

Rainwater as it falls from the sky is among the cleanest of water sources. However, the quality of rainwater is influenced by the atmosphere and collecting devices. This section looks at the potential sources that affect the quality of rainwater.

2.10.1 Particulate Matter

Particulate matter refers to smoke, dust, and soot suspended in the air. As rainwater falls through the atmosphere, it can incorporate these contaminants. Rainwater harvested from roofs can contain animal and bird faeces, mosses and lichens, dust, pesticides, and inorganic ions from industrial emissions (Kohler et al., 1997). In agricultural areas, rainwater could have higher concentration of nitrates due to fertilizer residue in the atmosphere (Thomas and Grenne, 1993). In industrial areas, rainwater can have slightly

higher values of suspended solids concentration and turbidity due to the greater amount of particulate matter in the atmosphere (Forster, 1999).

2.10.2 Roof Catchment

When rainwater comes in contact with a catchment surface, it can wash bacteria, dust, particularly during the dry and harmattan period as it contains high levels of metals, which can be toxic to plants, animals and humans. Some of these metals, especially trace metals, are bioavailable and can accumulate in the tissues of living organisms (Pelig-Ba, 2001). However, the longer the span of continuous number of dry days, the more debris are washed-off the roof by rainfall (Vasudevan, 2002). The inclination and direction of the roof also affects the run-off quality. Flat and gentle sloping roofs result in a slow flow of water over the roof surface when compared to roofs with steep inclines (Odnevall et al., 2000). Roofs facing the prevailing wind are affected more by the climatic conditions. This in turn will increase the rate of corrosion and weathering of the roof material (Pringle, 1998).

2.10.3 Storage Tanks

The more filtering of rainwater prior to storage, the less sedimentation and introduction of organic matter will occur within the tank (Abdul-Hamid, 2008). Sedimentation reduces the capacity of tanks, and the breakdown of plant and animal matter may affect the colour and taste of water, in addition to providing nutrients for the growth of microorganisms. If a tank is completely covered and organic debris is prevented from entering the water by means of a filter, any bacteria or parasites carried by water flowing into the tank will die-off. Thus

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water drawn from tanks several days after the last rainfall will usually be of better bacteriological quality than fresh rainwater (Thomas, 1998).

2.11 Conceptual Framework

The Figure 2.2 shows the conceptual framework employed to guide the study. The adopted conceptual framework is based on seven main areas namely the rainwater usage, rainwater quality, the design of RWH, parties involved in RWH, advantages and disadvantages of RWH, the application of RWH in building and RWH technology. Figure 2.2 is shown the seven main areas of RWH.
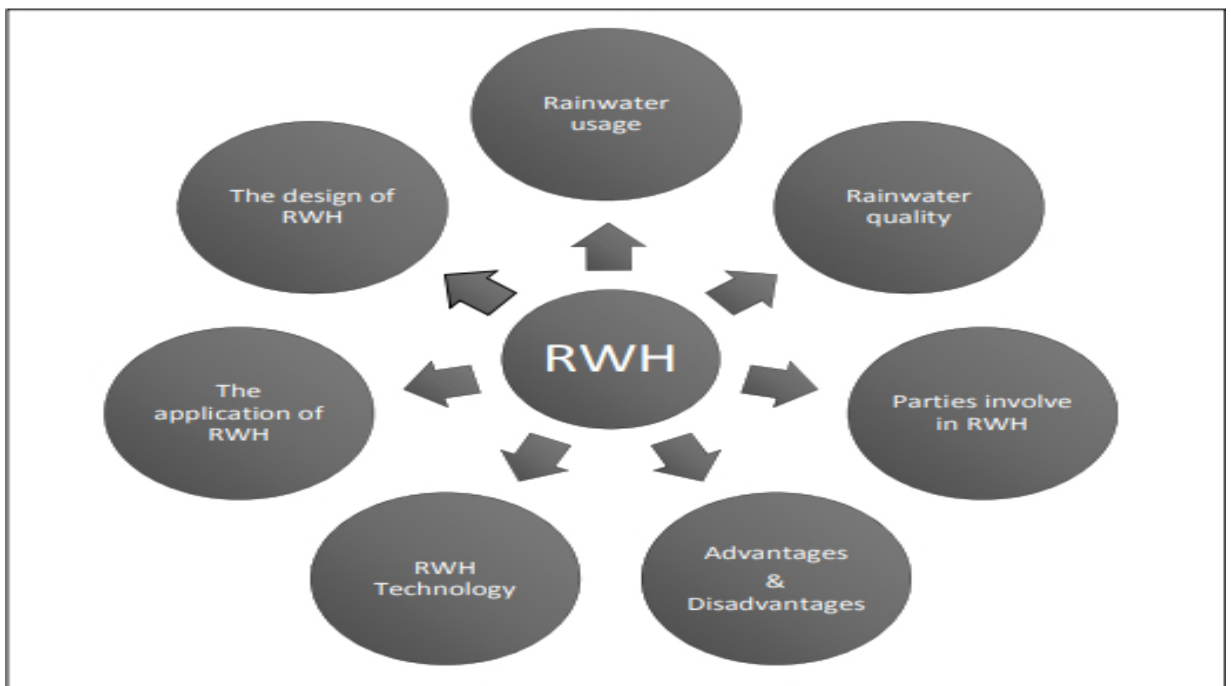
Figure 2.2 Diagrammatic presentation of the conceptual framework
Source: Author's Construct

The various topic under rainwater harvesting including the uses of harvested rainwater such for farming and domestic purposes (cooking, washing, flushing of toilet, gardening), will be thoroughly explored.

The design of rainwater harvesting system which is made up the catchment surface, the gutters (channels) and storage devices will be examined to establish its influence on water quality. How rainwater become contaminated through harvesting and storage.

The quality of harvested rainwater would be a critical area of concern and a thorough examination of its wholesomeness will be done at the laboratory of Ghana Water Company Limited Central Regional Office under the supervision of the regional chemist and his team. The application of chemicals to purify harvested rainwater.

Parties involve in rainwater harvesting will be assessed and their individual roles explored to the better adoption, uses, management of rainwater harvesting system in the district. The advantages and disadvantages of rainwater harvesting, especially in the developing world will be an area of concern. Rainwater harvesting has several merits such as supplementing or being the main household water supply and contamination of runoff due to its contact with catchment surface. The rainwater harvesting technology being either the simple or complex system will form part of this study.

2.12 Conclusion

The conceptual framework simplifies the research study, identifying the thematic area that would be thoroughly explored.

CHAPTER THREE

PROFILE OF STUDY AREA AND RESEARCH METHODOLOGY

3.1 Introduction

The chapter discusses the study area, why it was selected, types of houses and houses with rainwater system, economic activities, and occupation and health facilities in the study area. The chapter also looked at the approaches employed by the researcher in selecting samples, data collection, analyses and presentation of the data. Tamakloe et al. (2005), posits that methods refer to the formal structure of sequence of acts commonly denoted by instructions. The methodological approach applied in this study is the same to those in other fields, but the techniques and approaches to data collection and analyses varied as compared to other studies. These observations are supported by Festinger and Kartz (1966) who postulate that although the basic logic of scientific methodology is the same in all fields, its specific technique and approaches will vary depending on the subject matter. This chapter therefore highlights the multi-faceted approach that was employed to place the research work in focus from the initial stage to the final stage and provides a framework within which the research was conducted.

3.2 Study Area

The study was conducted in the Assin South District. It was carved out of the former Assin District by Legislative Instrument, LI 1760 of 2004. The district covers a geographical area of 1,187sq km representing 12 percent of the total land mass of the Central Region (9,826sqkm). It lies within longitudes $1^0.05'$ West and $1^0.25'$ West and latitudes $6^0.05'$ North and $6^0.40'$ North (ASDA, 2015).

It shares boarder with Foso Municipal to the North, Ajumako Enyan Esiam District and Asikuma Odoben Brakwa District to the East, Abura Asebu Kwamankese District to the South and Twifo Hemang Lower Denkyira District to the West (Figure 1).
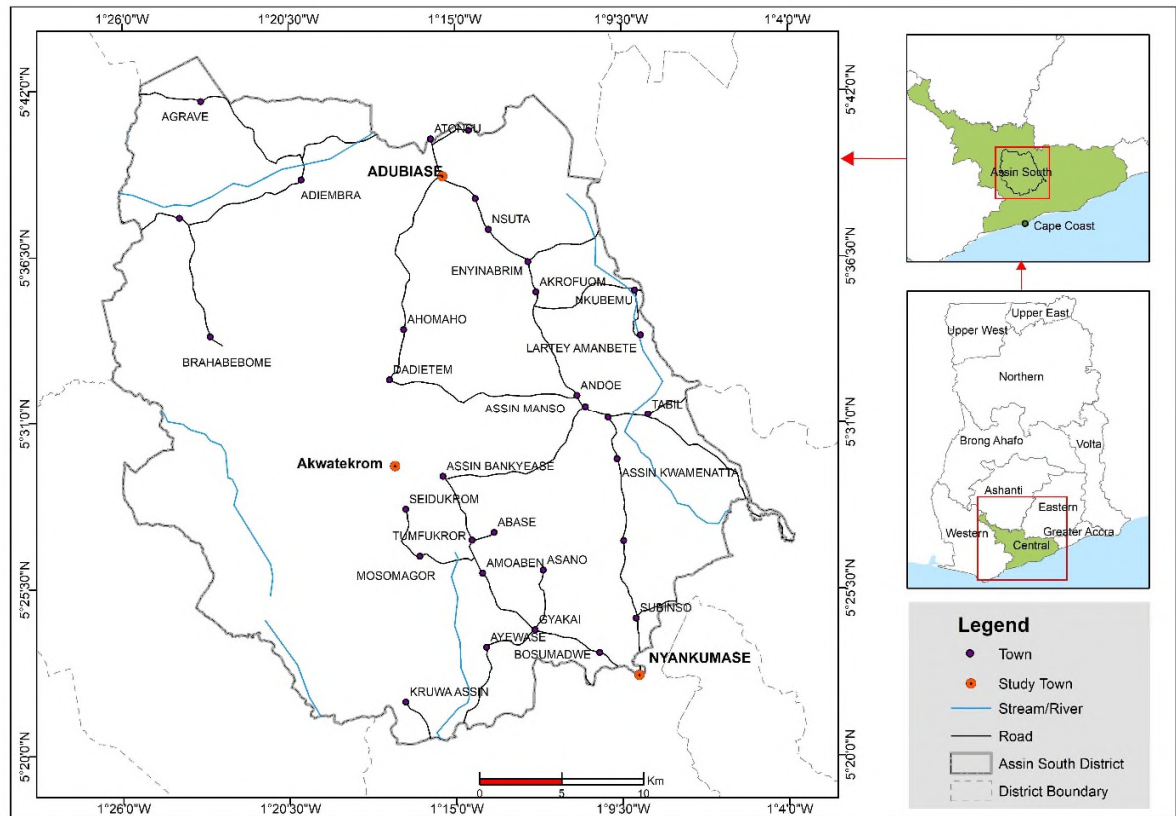
Figure 3.1 Map of Study Area
Source: Author's Construct

The study area experiences relative cool and moist south west monsoon winds that blow from the Atlantic Ocean for most part of the year – between December and February. However, the town experiences dry harmattan or North – East Trade winds which blow from the Sahara Region. Its dissipating effect is greatly reduced by long passage over the forest zone. Rainfall pattern is bimodal with the major raining season starting from April – July corresponding with the major farming season preceded by intermittent rainfalls in

February - March. The minor raining season starts from September – November (ASDA, 2015).

Assin South District is located within the Semi- deciduous and evergreen forest zones. The recorded annual average temperatures are high between March-April at 30ºC and August estimated at 20ºC hence a major raining season which begins in April and ends in July whiles the minor rain season commence from September to November. The district records an annual average rainfall between 1250mm to 2000mm and with average relative humidity between 60 percent and 70 percent (ASDA 2015; GSS, 2010)**.** The district is characterized by undulating topography and has an average height of 200m above sea level and many flood–prone plains. Swamps also abound in the town which serves as potentials for fish farming and dry season vegetable farming (ASDA, 2015).

3.2.1 Housing Characteristics and Population Characteristics

The total population of the Assin South District is estimated at 104, 244. The population is made up of 50,936 (49%) males and 53,308 (51%) females. The household size is estimated at 4.9 persons however this figure dropped to 4.4 persons per household in 2010 (GSS, 2010). A large size of the population of the Assin South District being 70.4% of households live in abode built with mud brick. Block or concrete takes the second spot with 25.1%. The rest of constructing materials are wood, land Crete and burnt brick with the percentages of 0.9, 1.0 and 1.2 respectively. The minute percentage of housing materials include metal asbestos, metal sheets, slate (0.3%), stone (0.1%), bamboo (0.2%) and thatch (grass), palm leaf and raffia (0.1%) (ASDA, 2015; GSS, 2010). The district has a very high percentage

of corrugated aluminium roofing sheets (80.0%) followed by thatch roofing (10.1) bamboo (4.7%), Slate (3.0%), concrete (0.4%) and others (0.5%). Available statistics show that 1.6% of household's use water closets, 36% use pit latrines, 9.9% use Kumasi Ventilated Improved Pit (KVIP) and 35.7% of the houses in the district use public toilets, which are well maintained and managed (ASDA, 2015).

3.2.2 Economic Activities

The Assin South District is largely an agrarian economy. The land is fertile and arable for food production and cash crop cultivation. Crops grown in the district could be categorized into mainly cash crops and food crops. Cash crops include cocoa, cashew, oil palm, orange, and food crops are cassava, plantain, coconut, cocoyam and yam. Cocoa and oil palm fruits are harvested and sold to marketing agents, cassava is both processed and sold in raw form to buck purchasers who transport it to Accra, Kasoa, Mankessim and Cape Coast. Cassava is processed into cassava dough by women and Rural Enterprise Programme (REP) assisted industries (ASDA, 2016). The proportion of males indigenes in economic activities are pegged at 74.3 percent which is a little above that of the females which stands at 74.4 percent. However the economic active population of the study area could be deduced from the workforce of both employed and unemployed total population of the study area. Ghana Statistical Service (2014) report reveals that agriculture, forestry and finishing is the commanding height of the economy with individual activities at 66.9 percent, then comes wholesale and retail businesses, auto mechanic and repairs at 9.2 percent, 8.1 percent to mining and quarrying occupation whereas a minute percentage of both arts and entertainment, and support services at 0.1 percent each. The employer proportion of the

study area point to a high percentage of private informal sector employing 92.3 percent and private formal sector absorbing 2.2 percent (GSS, 2010). Therefore, the private sector covering a wide percentage of 94.5 of the total workforce. The state employs a small percentage of the total active workforce of 5.5 percent hence taking the second spot in the employment scale. The population in government workforce within the study area is in the Assin South District Assembly, Ghana Education Service and Ghana Health Service.

The district has two major market squares namely Assin Andoe and Nyankumasi Ahenkro markets. Assin Andoe host the district market on Wednesday and Sunday, Tuesday and Friday is allocated to Nyankuamsi Ahenkro Market. These markets showcase all farm produce and commodities brought by farmers and traders far and near. Buyers and wholesalers from surrounding communities participate in the daily economic activities during market days. The District Assembly mobilizes revenue through taxes, market tolls, store rates and transportation rates during market days. This revenue builds up the internal generated funds of the Assin South District (ASDA, 2014).

3.2.3 Water Supply

Sources of water in the district include pipe- borne, borehole, unprotected well, protected well, rainwater, spring, sachet water, bottled water, tanker supply, river /stream and dugout water (GSS, 2010). According to 2010 Population and Housing Census, an estimated percentage of 46 of the total household units within the study area consume borehole, pump or tube well as their major sources of potable water. River/ creek account for 16.5 percent of water supply for the inhabitants of the study area. Public tap and standpipe cover the share of percentage 12.2 to households, people who rely on bottle and sachet water for their

daily water consumption accounts for 8.6 % portion of the water sources within the geographical area. The rest of the population rely on rainwater (ASDA 2014; GSS, 2010).

3.2.4 Sanitation

The sanitation situation in the Assin South District exhibits the same characteristics as other districts in Ghana. In the context of solid waste management, the phenomenal population growth has contributed to municipal waste production that far outstrips the district's capacity for containment and processing. There has not been substantial investment in environmental services to ensure that the solid waste generated is efficiently and sustainably managed. At the same time, the waste so generated is also becoming so diverse in its origin and forms and so pervasive in its impacts, through terrestrial, aquatic, and atmospheric ecosystems that it has the potential to adversely affect both the inhabited and uninhabited parts of the district. If this situation is not arrested, the footprint might be a disaster. The District Assembly (ASDA) has over the years instituted programs and policies to help curb the situation. However, high population growth couple with limited resources as well as other competing priorities have limited the ability of the city authorities to achieve the intended targets. This is evidenced from the mounting of waste at public places, uncollected waste bins at residential areas and overflowing public containers. According to the Population and Housing Census 2010, 57.5 of total household within the district dump solid waste by using common community refuse site, 13.0 percent of the population dispose solid waste materials using containers provided by District Assembly and Zoomlion Company Limited positioned at community dump sites followed by 12.5 % of people dumping their solid waste anyhow and the percentage of 8.6 people bury and burn

their solid waste.

3.3 Research Methodology

The strength and/or validity of the findings of any research depend on the methodology applied in the investigation. According to Collis and Hussey (2003), methodology refers to the overall approaches and perspective to the research process as a whole. It deals with issues involving what data will be collected, why the collection of that data, how it will be collected, where it will be collected and how it will be analyzed (cited in Neville, 2007). Similarly, Yogesh (2006: 88) noted "the methodology consists of procedures and techniques for conducting a study." Naville (2007:6) defined methods as the "application of various specific tools for the collection and analysis of data". Cohen et al. (2007), noted that a method refers to various approaches used to gather data which becomes the basis for interpretation and prediction.

3.3.1 Research Design

Research design plays a very important role in any scientific research. It helps to carry out the research task in a scientific and valid manner. Kerlinger (1986:279) indicated that "the research design is a plan, structure and strategy of investigation so conceived as to obtain answers to research questions or problems. The plan is the complete scheme or program of the research. It includes an outline of what the investigator will do from writing the hypotheses and their operational implications to the final analysis of data" (cited in Kumar 1999:74). The research design that was adopted for this study was a cross-sectional survey. They are "designed to study some phenomena by taken a cross- section of it at one time" (Babbie, 1989:89 cited in Kumar, 1999:81). This design is appropriate for studies that

intend to find out the incidence of a problem or issue. A mixed method approach was employed to collect data for this study. According to Creswell et al. (2007), the mixed method approach combines both quantitative and qualitative methods to inquiry and this makes the overall strength of the study greater than either quantitative or qualitative research (cited in Creswell, 2009). Another reason for the preference of a mixed method is to accomplish the logic of triangulation as one method (interview, questionnaire etc.) cannot fully elicit all relevant data. The combination of both methods makes it possible to cross check the data gathered by different methods (Denzin 1989, cited in Baaberiyir, 2009). The genesis of Mixed Method Approach could traced to Campbell and Fiske whose approach is that the result from one method could help develop or inform the other method of study and a research could nest a method within another method that can create a broad understanding of several stages or components of data analysis (Tashkkori and Teddie, 1998).

3.3.2 Data Sources

For a study to accomplish its objectives, data is extremely important. This study required data from two major sources, that is primary and secondary data sources.

3.3.2.1 Primary Data Sources

For the purposes of understanding local communities' rainwater harvesting strategies and storage systems; investigate the physio-chemical properties of harvested rainwater; examine the micro biological properties of harvested rainwater and to examine trace metal content of harvested rainwater in Assin South District, primary data were collected largely

from households in communities and other relevant institutions, organizations and departments that have responsibilities in managing water. This data provided current information on the topic under investigation and as a means to accomplish the objectives of the study.

3.3.2.2 Secondary Data Sources

An essential component of data for this study is secondary data. This data refers to data already processed, analyzed and presented. This data is available and only needs to be extracted. Extensive literature search was undertaken to obtain the relevant data. Secondary data are available from sources such as books, journals, magazines, periodicals, dissertations, newspapers, government reports, discs and internet. Secondary data was relied on to understand what authors have written and said about the issues under investigation. These aided the whole study process as in finding answers to the research questions and ultimately achieve the research objectives.

3.3.3 Sampling Design

The sampling design that was employed was both probability and non-probability sampling. The purpose of sampling is to reduce the population to a reasonable size to facilitate the conduct of a research. The reduction of population size ultimately reduces the expenses for the study. Also, a research without sampling might consume too much time, and hence sampling saves time.

3.3.3.1 Sampling Techniques

Sampling may be described as the act or technique of selecting and studying characteristics of only some segment of people, situation or items within a given group for the purpose of determining parameters of the whole population (Kane, 1998). According to Pratt and Loizos (1992, 60), sampling is where portions of the population is taken for the study because the population is large and will cost too much time, money and effort to question every one. Also, Blommers & Lindquist (1996), are of the view that sampling as a measurement or observation made of a limited number or sample of individuals or objects promotes generalization on references drawn about still larger groups or populations of the individual or object that these samples are supposed to represent. Ahuja (2001), is also of the view that a sample is that part of the population which is studied in order to make inferences about the entire population. Sampling can therefore be defined as taking any portion of a population or universe as representative of that population or universe (Osuala, 2001). The preference for samples over using entire population has been highlighted by many scholars. The goal of sampling according to De Vaus (2002) is to mirror the total population it is designed to represent. The reason why in research, sampling is preferred to complete coverage of the population is the fact that, sampling saves resources, labour, time, and permits a higher overall level of accuracy than full enumeration (Moser & Kalton,1971). This permits the generalization of the entire population with a high level of confidence. Millar (1999), posits that a study of representative samples is often better than basing studies on entire population who may be providing similar responses to particular interview question. However there is no guarantee that any sample will be precisely representative of the population from which it comes. Consequently, a sample is expected

to be neither excessively large nor too small but optimal. Such a sample should fulfill the requirement of efficiency, representativeness, flexibility and reliability (Creswell 2006). The study therefore considered the requirement above including the parameters of the population to be studied, its size, distribution and the cost of study (Twumasi 2001; Kane, 1999).

The study employed the sequential mixed method sampling strategies comprising the two main sampling technique; probability and non- probability sampling. The quantitative survey preceded the interpretive data gathering process even though according to Morgan (1998), mixed method designs starts with a qualitative pilot study followed by quantitative research. The sequential mixed method sampling entails ''the selection of units of analysis for a mixed method study through the sequential use of probability and purposive sampling strategies'' (Johnson and Onwuegbuzie, 2006). Kemp et al (2003), also posits that, in the mixed method sampling, information from the first sample (Typically derived from probability sampling procedure) is often required to draw the second sample (typically derived from purposive sampling procedure).

Preliminary field visits were embarked upon by the researcher prior to sample selection. This was because data gathered from the District Assembly indicate that not all households in the district capital depended on rainwater and therefore it was important conduct the preliminary visits to ascertain the best sampling technique to adopt. The visits were carried out between March and April 2017. The choice of this date yielded positive results as it was the time rainfall was intense and therefore the researcher could identify houses that practice rainwater harvesting. The preliminary visits were so beneficial to the researcher

because he used the visit to interact unofficially with household heads and the District Assembly officials where the main goal of the research was made known to them. Arrangement on where to lodge during data collection was made during the preliminary visits.

Based on the preliminary visits, some criteria for sampling selection was developed as follows:

1. A household was selected based on the fact that they have no in-house piping system and that they depend solely on rainwater for more than eight months of the year

2. That a household has rainwater collection and storage thank of the size of more than three barrels.

3. That rainwater was harvested from corrugated aluminum sheet.

With this criteria, 52 houses were identified. Using the census method, all the 52 houses were selected for the study. After selecting the houses, the purposive sampling was then employed to identify recognized authorities and population possessing specialized knowledge in the subject under investigation. According to Maxwell (1997:87), purposive sampling is a type of sampling in which "particular settings, persons, or events are deliberately selected for the important information they can provide that cannot be gotten as well from other choices". The purposive sampling was done with great caution in order to ensure that the quality and reliability of the information acquired was not sacrificed by the shortfalls of the methods and techniques (Twumasi, 2001). Therefore this technique was applied in choosing four (4) institutions involved in water management in the District.

The institutions selected were Ghana Water Company Limited, Community Water and Sanitation Agency, District Environmental Health Unit and the District Planning officer.

3.4 Data Collection Approach

This section outlines the various methods used in gathering data for the research. Methods employed include questionnaire, interviews, focus group discussion, (FGD) and personal observation.

3.4.1 Questionnaire Survey

Questionnaire survey was administered to all the fifty-two selected houses. The questionnaire was pre-coded with a few open-ended questions that required information on perceptions and attitudes. Local community members who were trained by the researcher undertook the questionnaire survey. The questionnaires were administered to the principal homemaker of each household (generally a woman) because women are deeply involved in household water management than men (Owusu-Sekyere et al., 2016). Questionnaire is one of the most widely used instruments for collecting data in survey research. Bryman (2004) suggests that the appeal of the questionnaire partly stems from its cheapness and quickness in terms of administration, the absence of the interviewer effect and its convenience for correspondence. The questionnaire for the household survey was developed to cover some aspects of the objectives of the study which was to investigate issues concerning the perception on rainwater use, harvesting strategy, storage and other quality issues. The instrument was divided into appropriate sections to allow for the systematic collection of data from the selected households. The issues covered in the

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survey include: the socio-economic profile of households; household source of water supply, sanitation and general water contamination. The face-to-face approach was adopted during the questionnaire survey. The face-to-face approach was adopted because of the respondents' busy schedule and limited educational accomplishment. There were many instances where the researchers had to read the items on the questionnaire over and over again, and also interpreted in other local languages before the appropriate responses were obtained.

3.4.2 Focus Group Discussions

Focus Group Discussions (FGDs) are deep interaction with people of a homogenous group between seven and twelve persons, which enables the researcher to tap or draw information in a particular area of interest that would be difficult if not impossible to obtain using other methodological procedures (Krueger, 1988; Kumekpor, 2002). It allows the researcher greater insight into why people think or hold certain opinions. Krueger (1988:18) outlines the feature of FGDs as interviews with people numbering between seven and twelve who possess certain characteristics (relatively homogenous and unfamiliar but knowledgeable in the topic of concern) to provide data of a qualitative nature and in a focused direction. Nine focus group discussions were held with the selected households categorized into landlords, opinion leaders and ordinary residents. This was used to fertilize ideas on household rainwater harvesting and storage strategies, and elicit information on the subject of the study and also to assess their priorities regarding improvements. This approach is deemed appropriate when the objective of the research is to explore attitudes or reactions of a group or community in response to some commonly experienced aspects of their

environment (Tsiboe, 2004). Through such interactive discourses, participants are able to offer insights on the perspective of the community, revealing clues to the social contexts that shape their opinions (Saleh 2002). Three of the focus groups had seven male participants, another three set of the focus groups had seven female participants and the last set of the group composed of three men and four women in each group. Issues discussed during the FGDs included the question of access to water, water quality, their knowledge and the extent of negative and possible health impacts of rainwater, and recommendations for improvements. All the proceedings, which were mainly in the local language, were recorded and later transcribed, analyzed and organized around the key themes.

3.4.3 Expert Interviews

Detailed interviews were held with the Regional Water Quality Assurance Manager of the Ghana Water Company Limited, Central Region, Community Water and Sanitation Agency, District Environmental Health Unit and the District Planning officer. These interviews were carried out to identify the constraints to policy implementation and service delivery. Interviewing is a useful way of collecting qualitative data because the technique is 'introspective' and allows respondents to report on themselves, their views, their beliefs, practices, interactions and concerns (Freebody, 2003). Besides, most people are more willing to talk in an interview than the case would be if they were asked to write or fill out a questionnaire (Robson, 1993).

3.4.4 Field Observation

According to Yin (2004), observations are a form of evidence that do not depend on verbal behaviour, and the method enables the investigator to observe the phenomenon under study directly. Miller and Brewer (2003) have categorized observation into 'unobtrusive observation' and 'participant observation' based on the degree of participation by the researcher, and into 'covert' and 'overt' observations based on the level of awareness subjects have of being observed. The phenomenon under study, rainwater harvesting, is one which lends itself to direct field observation. Thus, in addition to questionnaires and interviews, the researcher also conducted field observation to gather data on such things as standard of maintenance and environmental quality in the surrounding or nearby communities. In the course of the field observation, photographs were taken.

3.5 Secondary Data

The analysis of secondary data is one important source of data for social science research. As observed by Miller and Brewer (2004), documents are a good place to search for answers and they provide a useful check on primary information that has been gathered. Apart from that, documentary analysis allows the analyst to become thoroughly familiar with the materials and helps to save time as well as help corroborate and strengthen the evidence gathered using other tools (Robson, 1993). To this end, published and unpublished books and reports, articles, metropolitan development plans, textbooks, mass media reports and the Internet were consulted. In addition, cartographic and ordinance maps of the study area were used.

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3.6 Pre-tests

Research instruments were pre-tested at Assin Ngresi (a community in the district) to fine tune and determine the feasibility of the structured questionnaire. Assin Ngresi was chosen for the pre-test because water supply conditions there are very similar to those of the selected communities namely Assin Adubiase, Assin Akweteykrom, and Nyankumasi Ahenkro.

3.7 Issues of Validity and Reliability

The importance of testing for validity and reliability of research instrument to be used in collecting data for studies of this nature cannot be over looked. Cohen et al (2000), posits that validity refers to the extent to which the research instrument records what it is intended to record. Neuman (2004) also supported this opinion by mentioning that validity means truth that can be applied to the logical tightness of experimental design, the ability to generalize findings outside the study, the quality of measurement and the proper use of procedure. Validity is therefore concerned with the accuracy of measurement. On the other hand, reliability of an instrument concerns its consistency of measurement. Thus reliability refers to the extent to which an instrument measures the same way each time it is used under the same conditions with the same objects. According to Neuman (2004), Reliability is the dependability or consistency of the measure of a variable. In order to ensure the validity and reliability of research instruments, Burns (2000) stated that "research has a great investment in reliability and validity''. If the data is not reliable and valid, if the assessment techniques are not reliable and valid, if the design features do not create

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satisfactory internal and external validity, then the research is worthless in scientific aye. Greater care was taken by the researcher to achieve reliability and validity of research instrument by employing varied instruments such as questionnaire, observation, interviews and focus group discussion to complement each other so as to come with credible results.

3.8 Rainwater Quality Test

In order to determine whether rainwater catchment is an option worth considering for the water scarcity issue in the district, water quality and the overall advantages had to be considered. According to the World Health Organization's Design Guideline for Rainwater Catchment (2001), when analyzing the feasibility of rainwater harvesting, three factors must be considered: technical aspects which in this case include water availability, precipitation, demand and water quality; economics including a comparison of the costs of implementing this system with the costs of obtaining water through other means; finally, the social factor which include the community's response to rainwater harvesting, their involvement and interest. This study however concentrates on the first factor and specifically concentrates on rain water quality. To this end water samples were collected from three different locations namely Assin Adubiase, Assin Akweteykrom, and Nyankumasi Ahenkro and rooftop materials and analyzed to determine their quality. Water quality standards were measured according to the Ghana Water Company's Technical Regulation for Potable Water.

Three samples of rainwater was analyzed, they were water harvested direct from the sky (coded as SKY in the thesis) this process involved the placing of a basin on top of a table covered with plain rubber sheet soaked in acid and then placed in an open field: water harvested from roof top (coded as ROOF in the thesis) this was done by placing basin on a three feet table covered with a plain rubber sheet soaked in an acid solution and rainwater stored in a storage tank – a cup with long handle was used to fetch the harvested water from the storage device (coded as TANK in this thesis). Care was taken to ensure that no accidental contaminations occurred during sampling. Sample containers were soaked in acid solution overnight prior to sample collection, followed by proper rinsing with distilled-deionized water and the stored rainwater, before the samples to be analyzed were collected from the storage tanks. These sample were coded as SKY representing rainwater harvested directly from the sky: ROOF representing rainwater harvested from rooftop: TANK representing rainwater fetched from the storage device. The purpose of the three types of the sample test was to allow for comparative analysis. The samples were all collected in Assin South District between 15th July and 10th August 2017. This period was taken because it was the time rainfall was continuous in the district and that the early rainfall was presumed to have washed away the contaminated surfaces. At this period rainwater was considered to be pure/clean and therefore any contamination was deemed to have come from the harvesting and storage facility. It was also the period preceding the long dry period and therefore water supply from the Ghana Water Company Limited was irregular. Majority of households therefore relied on rainwater.

3.8.1 Physico-Chemical Analysis of Harvested Rainwater

The physico-chemical analysis of harvested rainwater samples- rainwater harvested directly from the sky (SKY), rainwater harvested from the roof catchment surface (ROOF) and rainwater fetched from the storage tank (TANK) encompassed Temperature, pH, Colour, Turbidity, Total Dissolved Solids, Electro Conductivity, and Total Suspended Solids. The indicators, method of testing and the equipment used is presented in Table 3.1

Table 3.1 Methods and apparatus used for analyzing the microbiological state of rainwater

Physico-Chemical Properties	Method of Assessment
pH Measurement	The Mettler Toledo pH meter was used. The meter was first calibrated and the probe rinsed with distilled water and dipped into the samples and the pH value for the sample appears on the digital scream and it was recorded.
Colour	The DR 2800 spectrophotometer with program number 120 was used.
Turbidity	The turbid meter was used with10mls of water samples from the three sources
Electrical Conductivity	The conductivity meter was used with beaker with 150mls of water samples from the three sources
Total Dissolved Solids	The I. Multiply electrical conductivity by 0.675 was to get T.D.S.
Temperature	Thermometer was used. The thermometer was immersed in the three samples of water

3.8.2 Microbiological Analysis

The study employed advanced test methods to study the microbial quality of rainwater collected from the different sources. Samples of all three points of rainwater collection were put into sterile polyethylene containers opened during rain. Taking into account the

washing away effect, portions of water were collected only after at least an hour-long, intensive fall. The samples were transported to the laboratory in a portable fridge in less than 6 hours. For each collected sample of water a series of microbiological assays (Table 3.2). Coliforms and *E. coli* were assayed in a standard way using procedures provided for by the PN-EN ISO 9308-1 and PN-EN ISO 9308-2 norm. Likewise, assays were performed for faecal streptococci PN-EN ISO 7899-2. Bacteria from the coli group and *E. coli* were additionally assayed with the use of a chromogenic medium. The medium makes the coli bacteria grow fast due to a combination of proper peptones and the MOPS buffer. The combination of two chromogenic substrates reveals all intestinal bacteria and *E. coli.*

Total number of bacteria was determined in accordance with PN-EN ISO 6222 also with an additional variant, where cultures are grown on agar supplemented R with extended incubation. Samples for cytometry analysis were prepared according to the own procedure. The difference between the number of all particles (assayed with Sybr Green) and the number of dead particles (assayed with propidium iodide) provides the overall number of living microorganisms. These tests are used to index hygienic quality because total coliform are usually associated with faecal contamination and thus, their numbers reflect the degree of pathogenic risks. Also, the tests are relatively easy to perform in comparison with analysis for specific pathogens. *Escherichia coli*, on the other hand are microorganisms found in large amounts in human and animal feces. The presence of these bacteria in roof-collected water may be accounted for by feces left by birds and small mammals (mainly in the case of the terrace). Another potential sources of faecal microorganism contaminants are wind-transported soil particles coming from organically

fertilized farming land and bio aerosol from freestanding biological reactors of the water treatment plant. The indicators, method of testing and the equipment used is presented in Table 3.2

Table 3.2 Methods and Apparatus for Analyzing the Microbiological Level of Rainwater

Indicator	Test method	Equipment
Overall mesophilic and psychrophilic bacteria count	plate culture and bacteria cultured on standard nutrient media (nutritional agar) and enriched ones (agar R); oxygen conditions	sterilizer, autoclaves, bacteriological culture cabinet, incubator, scales
Number of pathogenic bacteria - *Eschericha coli*	membrane filter technique and culture on selective and differential media; oxygen conditions	sterilizer, autoclaves, bacteriological culture cabinet, incubator, scales, a filtration kit
Number of pathogenic bacteria - *Enterococci (faecal streptococci)*	membrane filter technique and culture on selective and differential media; oxygen conditions	sterilizer, autoclaves, bacteriological culture cabinet, incubator – 37oC, scales, a filtration kit
Number of spore bacteria *Clostridium perfringens*	plate culture and cultures on nutrient, selective, and differential media; oxygen conditions	sterilizer, autoclaves, bacteriological culture cabinet, incubator – 37oC,

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live and dead bacteria cell count	cytometry analysis with fluorescent dye	flow cytometer PARTEX, fluorescent dyes: Syto Green, and propidium iodide, bacteriological culture cabinet, incubator – 37oC

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3.8.3 Trace Metal Analysis of Harvested Rainwater

Trace metal analysis of harvested rainwater samples- rainwater harvested directly from the sky (SKY), rainwater harvested from the roof catchment surface (ROOF) and rainwater fetched from the storage tank (TANK) covered Salinity, Zinc, Total Iron, Manganese, Calcium, Magnesium, Arsenic, Chromium, Cyanide, Fluoride , Nitrite , Nitrate, Ammonia, Chloride, Phosphate, Sulfate , Total Hardness, Calcium Hardness, Magnesium Hardness, and Alkalinity. The indicators, method of testing and the equipment used is presented in Table 3.3

Table 3.3 Methods of Analyzing Trace Metal level of   Harvested Rainwater

Trace Metal	Method of Assessment
Total Hardness	A digital titrator was used. A graduated cylinder measure 20mls of sample according to titration cartridge number (0.800) was poured into a conical flask. 2mls of buffer solution, hardness 1, and swirl to mix. Multiple titre value by digit multiplier (5.0) provided, result is in mg/L.
Calcium Hardness	A digital titrator was used. First, water samples of 20mls was taken from the various sources. 2mL of 8N potassium hydroxide standard solution were added and swirl to mix. One CalVer 2 calcium indicator powder pillow was also added and swirl to mix. Multiple titre value by digit multiplier (5.0) provided, result is in mg/L
Magnesium Hardness	This was done by subtracting total hardness value from calcium hardness value to get magnesium hardness in mg/L
Total Alkalinity	A 50mL of sample of water was poured into a conical flask. Three drops of methyl orange was added and this was titrated with sulphuric acid (H_2SO_4) 0.02N.
Chloride	A 40mL of sample of water was poured into a conical flask. Contents of one chloride 2 indicator powder was added and this was titrated with silver nitrate ($AgNO_3$)

Nitrate	A 10mL of sample of water was poured into a conical flask. Contents of one NitraVer 5 Nitrate Reagent powder. Spectrophotometer DR 2800 and program number 355 was then used
Manganese, Iron, Sulfate	A spectrophotometer DR 2800 and a program number 290 was used. 10mL of water samples were poured into square sample cell, 12 drops of alkaline-Cyanide Reagent solution was then added to each cell to determine the level of each of the trace metals.
Ammonia	A spectrophotometer DR 2800 and a program number 385 was used. 10mL of water samples were poured into square sample cell, the contents of one Ammonia Cyanurate Reagent powder was then added to determine the Ammonia
Phosphate	A 10ml sample of water was fetched from the various sources, contents of one PhosVer 3 phosphate was then added to determine the phosphate content.
Fluoride	A spectrophotometer DR 2800 and a program number 190 was used. A 10ml sample of water was fetched from the various sources, contents of SPADNS Reagent was then added to determine the fluoride content.
Copper	A spectrophotometer DR 2800 and a program number 135 was used. A 10ml sample of water was fetched from the various sources, contents of one CuVer 1 Copper Reagent powder was then added to determine the copper content.

Zinc   A spectrophotometer DR 2800 and a program number 780 was used. A

10ml sample of water was fetched from the various sources, contents

of ZincoVer 5 Reagent powder was then added to determine the zinc

content.

Aluminium   A spectrophotometer DR 2800 and a program number 10 was used. A

10ml sample of water was fetched from the various sources, contents

of AluVer 3 Aluminium Reagent Powder was then added to determine

the Aluminium content.

The analyses were conducted in the laboratory of Ghana Water Company Limited Regional

Office, Cape Coast.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Introduction

This Chapter presents analysis and interpretation of the data collected from the field. Data analysis is one of the fundamental processes in research operations. Failure to analyze the collected data from research renders them useless to policy makers and undermines the real advantage of research (Muwonge, 2006). Some of the issues captured include rainwater harvesting strategies and storage systems in Assin South District, the physio-chemical properties of harvested rainwater, micro biological properties of harvested rainwater and trace metal content of harvested rainwater in Assin South District. Therefore, this analysis has been grouped based on four thematic areas in addition to some demographic characteristics relevant to this study.

4.2 Demographic Information

The demographic characteristics examined were age, marital status, religious and educational background and occupation of respondents. This demographic information was included to highlight whether the characteristics of respondents were homogenous or varied. Research by Owusu and Oteng-Ababio (2014) emphasized the need to examine the demographic characteristic of respondents since it has effect on the behavior of research participants. Out of the 52 household respondents interviewed, 75% were females, far higher than the proportion of male respondents of 25%. Majority of respondents were women because the cultural arrangements of the study locality were such that household environmental issues including water access and its related activities were mostly the responsibility of the women. They were therefore in a better position to give accurate

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answers. Again, women were also responsible for managing environmental hazards which requires patients and tactics to minimize their adverse effects in support of the claim by Owusu-Sekyere, (2014) that women are generally in control of internal activities within the household level during all phases of the disaster cycle and the perception about gender roles hinders man involvement in disaster management.

4.2.1 Age of Respondents

The first demographic characteristics that was examined was respondents' age (Table 4.1).

Table 4.1 Age of the respondents

Age Bracket	Frequency	Percentage
>30 years	9	17.31
31 – 40 years	18	34.62
41 – 50 years	20	38.46
51 and above	5	9.62
Total	**52**	**100**

Table 4.1 shows that majority of respondents were in between 31-50 years. Out of the 52 respondents who were interviewed, 17% were less than 30 years while 9% were more than 51 years (Table 4.1). Although the youth has been described as the vibrant human resource, the youth were under represented in the sample. This may be due to their low involvement in rainwater harvesting and their limited roles in household decision taken.

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4.2.2 Educational Level of Respondents

Education is very important to cope up with the changes and evolutions occurring in the society day by day. Definitely education is necessary for the choice of access to water, storage strategies and water quality issues. Research by the WHO has shown that educated households are more likely to treat water before use than poorly educated households. Again, educated households are the ones who will take decisions for people to benefits and take the country ahead in the direction of development. In line with this thinking, the education background of the respondents were examined (Table 4.2).

Table 4.2 Education level of the respondents

Educational Level	Frequency	Percentage
No Education	13	25
Basic	12	23.08
Secondary	15	28.85
Diploma	10	19.23
Degree	2	3.85
Total	**52**	**100**

From Table 4.2, majority of respondents had completed Secondary and Diploma level of education. As shown in Figure 4.2, 3.85 percent had University first degree, 19.23 percent had Diploma, a total of 15 respondents equivalent to 28.85 percent had secondary school education, and a total of 13 respondents which is 25 percent had no formal education. The rest of the respondents held certificate in Basic education. This is in line with Post et al.

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(2003), argument that education enhances women's participation in politics and economic activities. Evidence of this was found in Bangladesh where Ahmed (2000) realized that the introduction of Non-Formal Education for women led to their visibility in the family and in social affairs and for example among women household heads led to their proper adoption of good hygiene practices. This is in line with Parasuraman (1991), argument that education enhances proper utilization of water and economic activities.

4.2.3 Marital Status of Respondents

Marriage is an important and revered social institution in Africa. It serves as a tool for ensuring social reproduction, raising of families, socializing children and caring for the sick and elderly. Because of these roles associated with marriage, it is sometimes argued that women's participation outside the domestic space is restricted since women carryout most of these responsibilities. Therefore, women who participate in politics are mostly likely to be unmarried, divorced or single mothers. The marital status of study participants in shown in Table 4.3.

Table 4.3 Marital Status of the respondents

Marital Status	Frequency	Percentage
Married	26	50
Single	18	34.62
Widowed	3	5.77
Divorced	5	9.62
Total	**52**	**100**

From Table 4.3, majority of respondents had completed are married having a percentage of 50; single fellow respondents occupy a portion of 34.62 percent, and widowed and divorced respondents had a percentage of 5.77 and 9.62 respectively.

Table 4.4 Religious Distribution of Respondents

Religion	Frequency	Percentage
Christians	30	57.69
Muslim	15	28.85
Traditionalist	5	9.62
None	2	3.85
Total	**52**	**100**

The sample population totaling fifty-two (52) had 30 Christians, 15 Muslims, 5 traditionalists, and two people practiced no religion being 57.69%, 28.85%, 9.62% and 3.85% respectively.

Table 4.5 Occupational Distribution of Respondents

Occupation	Frequency	Percentage
Farmers	28	53.85
Traders	14	26.92
Artisans	4	7.69
Civil Servants	6	11.54
Total	**52**	**100**

A total of 28 farmers, 14 farmers, 4 artisans, 6civil servants within the study area. These people practiced rainwater harvesting.

4.3 Rainwater Harvesting Strategies in Assin South District

This section answers objective one of the study which seeks to investigate rainwater harvesting strategies adopted by households in the Assin South District. Rainwater is a free source of nearly pure water and rainwater harvesting refers to collection and storage of rainwater and other activities aimed at harvesting surface and ground water. It also includes prevention of losses through evaporation and seepage and all other hydrological and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit such as a watershed. In general, water harvesting is the activity of direct collection of rainwater. The rainwater collected can be stored for direct use or can be recharged into the ground water. The research study revealed that households in the Assin South District harvest rainwater from diverse
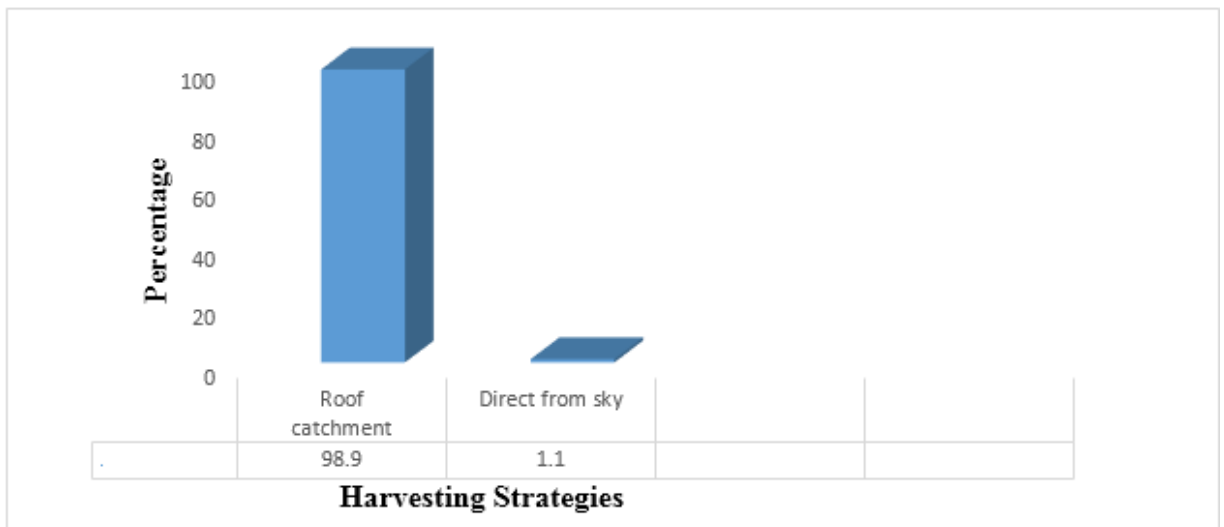

Figure 4.1 Harvesting Strategies

Figure 4.1 shows that 98.69% of respondents harvest rainfall through roof catchment surface while 1.1 % of the respondent harvest rainfall direct from the sky. The idea to add the type of catchment to the questionnaires was vital as the medium of runoff entrapment has a strong correlation with the wholesomeness of harvested rainwater. Apart from rainwater harvesting strategies, the study also considered the type of catchment roofs that were used. It was important to investigate the catchment roof since over 98% of respondents indicated that they use roof catchment for rainwater harvesting. The catchment area is the first point of contact for rainfall. For the vast majority of tank-based rainwater harvesting systems, the catchment area is the roof surface.

Among the catchment roof surfaces, 86% person was made up of Aluminum Zinc, 4% was made of coated Zinc, and 7% was slate with only 1% made of Bamboo (Figure 4.2). Aluminum or pre-painted Zinc or Aluminum Zinc was popular because it is the most common type of roofing system in Ghana in general and the study area in particular. It is the best roofing material for a rainwater harvesting system also because it has a wider collection surface and the perception that water harvested from Aluminum zinc is safer and can be consumed than from the other sources such as coconut leaves and bamboo among others.
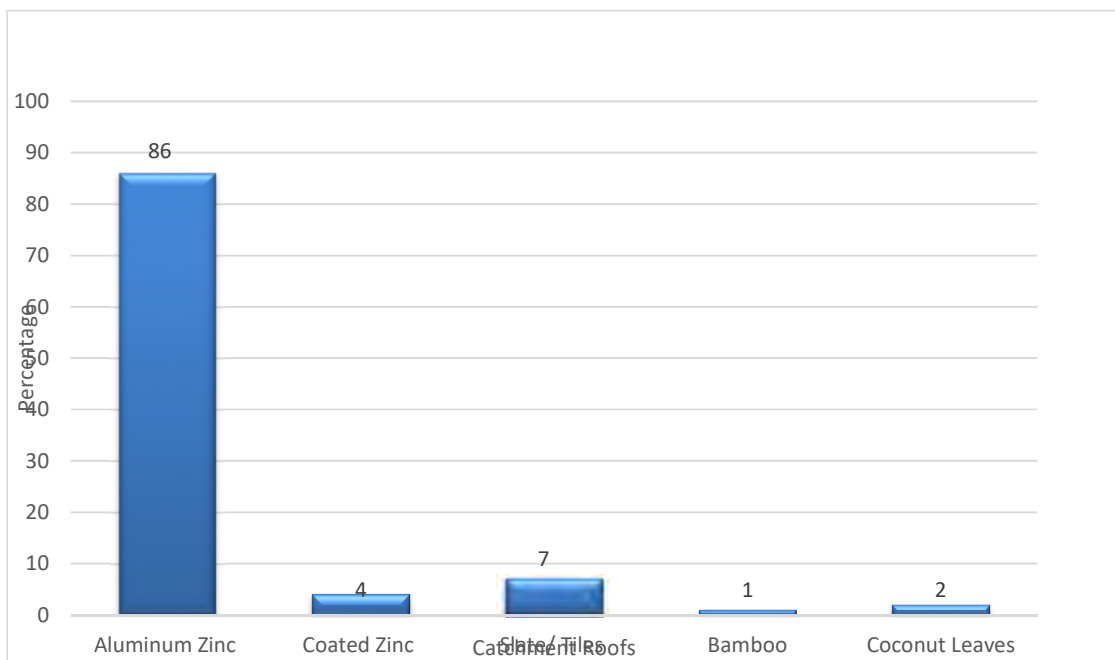
Figure 4.2 Types of Catchment Surfaces

The material of the roof is important because to a large extent, determines the level of contaminants that may be on the roof. In an interview with the Regional Water Chemist of the Ghana Water Company Limited Cape Coast he explain:

> "*We recommend a metal roof because they easily shed contaminants. In all cases, it's important to avoid wood shingles or metal flashing that contains lead"*, he concluded.

The key informant further explain other factors that are important in rainwater harvesting using roof catchment:

> "*The slope of the roof is important. It affects how quickly water will runoff during a rain event. A steep roof will shed*

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runoff quickly and more easily clean the roof of contamination. A less-steep, flatter roof will cause the water to move more slowly, raising the potential for contamination to remain on the catchment surface. The roof on the right has a steep slope followed by a more gradual slope".

He further explained that the size of the catchment area or roof is also important as it determines how much rainwater that one can harvest. The area is based on the "footprint" of the roof, which can be calculated by finding the area of the building and adding the area of the roof's overhang. After examining the catchment sources, the study also analyzed rainwater storage strategies in the district. The results is presented in Figure 4.3 and Figure 4.4

Figure 4.3 Storage Devices for Harvested Rainwater in the Assin South District.
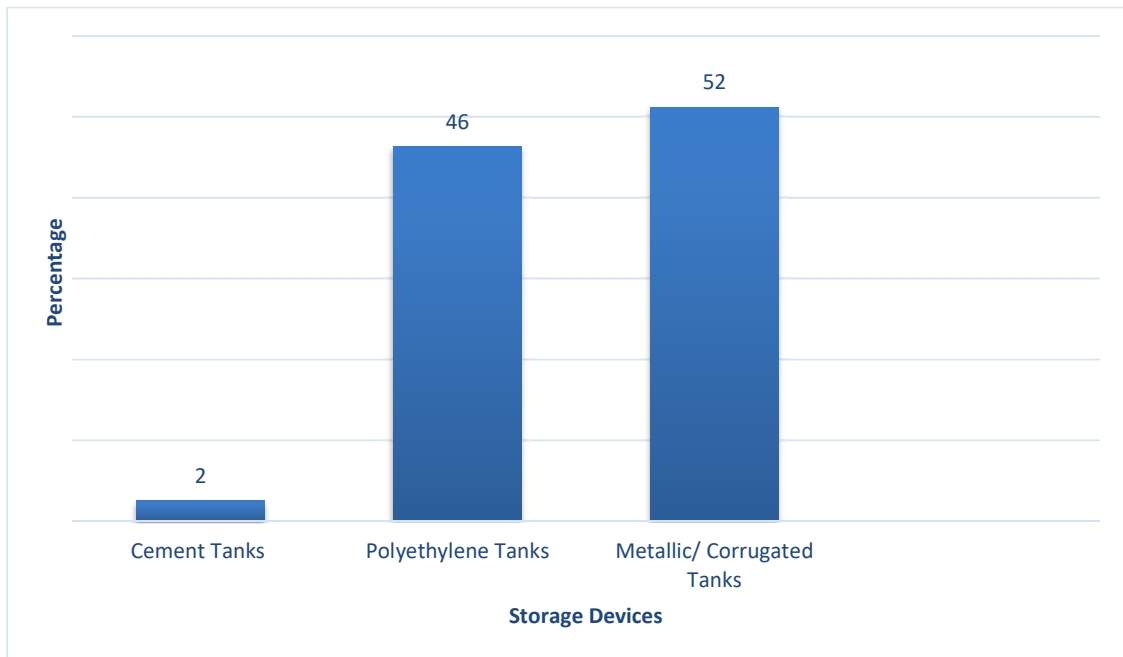
Figure 4.4 Types of Storage Devices

The research revealed that for 52%, the most common storage device was metallic corrugated tanks. This metallic corrugated tanks were placed under the gutters to collect runoff during rainfall the study further revealed that some metallic corrugated tanks have well-fitting lids while others did not but left open and occasionally, were covered with rubber sheet to prevent dirt from entering the water. Followed by metallic corrugated tanks was polyethylene tanks employed by 46% to store harvested rainwater. The polyethylene includes barrels, Poly Tank and big rubber basins locally called 'adom ara kwa'. Some of the barrels have well-fitting lids, others have small in-let which is connected with a pipe, and however some have no lids. Cement/ concrete tanks were few within the study area. A small number of respondents representing 2 % who have well-built Cement/ concrete tanks to store rainwater. These tanks were connected with filters and well laid network of pipes to convey water to and from the cisterns for usage.

4.4 Uses of Rainwater

Collecting rainwater is an excellent way to conserve scarce water resources. A basic rainwater collection system catches rainwater from the roof or other surface and channels it into a container for storage. Rainwater itself is generally clean, but it can pick up microorganisms, pollutants and debris when it hits the roof. This is why systems for rainwater use inside a home often include filtration or other treatments for safety (Tacoli, 2005). Perceived wholesomeness of rainwater or otherwise may also affect its use. For this reason the study sought the views of respondents on the purpose for which they use rainwater (Figure 4.5).
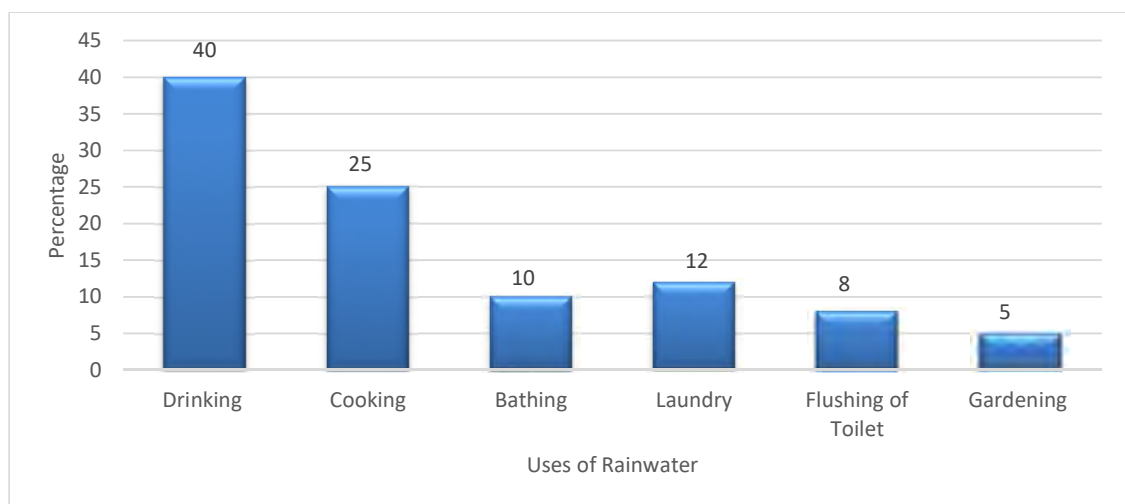
Figure 4.5 Uses of Rainwater

The research further revealed that respondents use harvested rainwater for varied purposes. Figure 4.5 shows that 40% of respondents claimed they use rainwater as their main source of drinking water. For 25%, rainwater is what they use for cooking. 12% uses harvested rainwater for laundry activities, 8% for flushing of toilet and So far only 5% said the use

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rainwater for gardening. Respondents gave varied reasons for their choice. For instance a 45 years old household head in interview explained why she likes using rainwater for bathing:

> *"I like to use rainwater for bathing because it lathers well. Once it is good for drinking then you must know it is good for bathing. When you pour small washing foam then you are good to go. It is good and so I and all my household will always use it".*

The use of rainwater for drinking, cooking, laundry, bathing, cleaning and gardening among others did not come as a surprise because as indicated in the literature, (Twumasi, 2001) rainwater is naturally soft, meaning there are less minerals dissolved in it than hard water. This is because rainwater has not flowed over rocks, through rivers etc. and picked up the salts and minerals that groundwater or mains supply might. The literature further indicates that human hair likes water that is soft, has a neutral pH and is free of heavy metals. Rainwater fits this perfectly (Venton, and Hansfords, 2006). For the same reasons, the human skin also likes the purity and neutral pH of rainwater. If you have sensitive skin, it can reduce some symptoms associated with hard water. Detergents and soaps also work more effectively in soft water. One will be able to get a great lather on their soap and will not need to use as much to get clean (Vaz, 2000). This also goes for washing clothes and the dishes – even washing-up liquid lasts longer in rainwater.

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4.5 The Physico-Chemical Properties of Harvested Rainwater in Assin South District.

This section covers objective two of the study which sort examine the physio-chemical properties of the harvested rain water. It is necessary to know details about different physico-chemical parameters such as colour, temperature hardness P^H, Sulphate and many others use for testing water quality. They are of special concern because water or chronic poison to humans. The physico-chemical analyses was key to determine the quality level of harvested rainwater. The wholesomeness of water is dependent on its physiological and chemical properties. Table 4.6 shows the average measurement of each parameter namely Temperature, pH, Total Dissolved Solids, Color, Turbidity, Electro Conductivity and Total Suspended Solids.

Table 4.6 Physico-Chemical of Harvested Rainwater

PARAMETER	GHANA STANDARDS	UNIT	RESULTS		
	Acceptable		SKY	ROOF	TANK
Temperature	29.0	^{O}C	25.9	27.8	27.6
pH	6.5-8.5	pH Units	6.9	7.1	8.8
Color	<15	Pt. Co	17	23	28
Turbidity	0 – 5.0mg/l	NTU	5.2	16.0	18.0
T. Dissolved Solids	0 – 3.0mg/l	mg/l	4.3	17.8	24.6
Elect. Conductivity	0 – 1.5mg/l	µS/cm	1.7	18.7	26.4
T. Suspended Solids	0 – 400mg/l	mg/l	410	520	567

4.5.1 The pH of the Harvested Rainwater

P^H is a measure of the acidity or alkaline of an aqueous solution. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. pH is related in several different ways to almost every water quality parameter; pH values higher than 8.5 favors viral hepatitis, a growth in water (WHO, 2008). The WHO and the Ghana Standards Board recommended levels for dam water pH is between 6.5 and 8.5. As shown in Table 4.3 the pH results for rainwater harvested from the sky directly and rain water stored in Tanks were within the given range of 6.5 and 8.5 which is the acceptable levels. However, the pH test results presented in Table 4.3, which was conducted on rainwater harvested directly from aluminum roof showed pH at 8.8. The results is above the WHO acceptable limit for water quality. This situation could have serious consequences on the health of the community because such condition could favour the prevalence of infectious hepatitis.

4.5.2 The Turbidity of the Harvested Rainwater

Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air. It is primarily a measure of the concentration of finely divided matter (colloidal solids), which affects the water's appearance and may contain micro-organisms. The units of turbidity from a calibrated nephelometer are called Nephelometric Turbidity Units (NTU). The measurement of turbidity is a key test of water quality.

Turbidity in open water may be caused by growth of phytoplankton. However, human activities that disturb land, such as construction, can lead to high sediment levels entering water bodies during rain storms due to storm water runoff. In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases. In water bodies such as lakes, rivers and reservoirs, high turbidity levels can reduce the amount of light reaching lower depths, which can inhibit growth of submerged aquatic plants and consequently affect species which are dependent on them, such as fish and shellfish. (Van Der Geest, 2011).

The WHO (2008) recommended level of water turbidity is 0 – 5mg/l and the results show that all the sources of harvested rainwater hand turbidity levels above the recommended standard prescribed by the WHO. As shown in Table 4.3, the turbidity levels of all the harvested rainwater were 5.2, 16.0 and 18.0 for SKY, ROOF and TANK respectively. These figures are well above the WHO and the Ghana Standards Authority acceptable levels 5 NTU. The reason for the heavy cloudiness of all was as a result of the human activities in and around the housing properties in the study area. These anthropogenic forces are causing considerable environmental degradation of the vegetation cover in the community. The surface of roofs has therefore become reservoirs for human/animal. The waste on the roofs are normally due to the activities of birds.

Observations from the field showed that when local birds feed from the environment, pathogens from diapers, honey buckets, household medical wastes and napkins among others can adhere to their feet and beaks, and then become dislodged onto surfaces of roofing and uncovered from water tanks among others. Of particular concern to

respondents in the interview section was the significant number of households that use rain catchment roof systems to collect (untreated) drinking water. An additional exposure pathway pathogens could thus be realized via bird feet-to-roofs, roof-to-rain water, and water-to-mouth (and to-hand during container dipping). What was of greatest concern to the respondents was the colony of crows that were constantly present in the communities because of the presence of a waste disposal site.

In an interview, a 45 year old woman had this to say:

"***If you fetch water and you do not cover it the crows will drop their feces in it"***. According to the chief of the study area:

"……the crow situation needs to be looked at as an emergency because their presence is a source of worry. They drop all sorts of particles in our storage containers and in the process pollute the water. Sometimes, they even drop their feces in the eaten bowls when they are left uncovered. Their presence is a real source of worry to us".

On the whole, the results (Table 4.3) show that all the parameters were above the recommended WHO and the Ghana standards though there were variations among the harvested rainwater sources. For instance, the difference between the pH value of harvested rainwater from the SKY and aluminum roofing sheet. That of the aluminum roofing sheet was greater than that of the SKY which indicates that there was significant level of pollution or contamination of the roofing material.

4.6 The Micro Biological Properties of Harvested Rainwater in Assin South District.

This section of the thesis fulfils objective three of the study which seeks to examine the micro biological properties of harvested rainwater in Assin South District. The Micro

Biological test was conducted to determine the presence of pathogenic bacteria in rainwater harvested from roofs, sky and storage facilities. The aim of the water quality analysis was to collect baseline water quality data on the various sources of household water supply in order to ascertain the underlying factors responsible for water contamination problems and evaluate their health implications on the population. The scope of work that was covered in the bacteriological analysis concentrated on *faecal coliforms* and *E. coli* contamination. These parameters were of priority because of its immediate link to human health. The tests were conducted in the Ghana Water Company Limited, Central Regional Laboratory by the researcher with the aid of three (3) water chemists. The three (3) rainwater sample were collected namely rainwater harvested directly from the sky coded "SKY", rainwater collected from roof catchment surface labeled "ROOF" and rainwater fetched from the storage device and named "TANK". The parameters are Total Coliforms, E. *coli* and *faecal coliforms* and below is the results after the analyses after 48 hours.

Table 4.7 Results from Microbiological Analyses of Rainwater

PARAMETER	Acceptable GWCL Guidelines Drinking Water	UNIT	RESULTS		
			SKY	ROOF	TANK
Total coliforms	0 CFU	MPN/10 ml	0	12	15
E.coli	0 CFU	MPN/10 ml	0	2	3
faecal coliforms	0 CFU	MPN/10 ml	0	11	13

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undergo prior treatment. This is partially supported by limited epidemiological studies (Heyworth, 2006). Additionally, a previous research study has reported that rainwater harvested quality is generally acceptable for drinking and household use and poses no increased risk of gastrointestinal illnesses when compared with mains water (Najmi, 2008). Contrary to the results from rainwater harvested from the sky, the total coliform counts in rainwater harvested from roof tops and harvested rainwater stored in tanks were higher. This was due to the level of contamination. In an interview with the Central Regional Quality Control Officer of Ghana Water Company Limited he explained:

"The source of highest contamination levels from the roof is mainly due to pollution from the wind and activities of birds. When the wind blows, all kinds of materials are deposited on the roof. Again, birds also deposit materials they have picked from the environment on the roofs so these contaminants pollute the rain water. It is for his reason that Water collected from these sources after rainfall is always found to contain active cells of anaerobic bacteria. These organisms are an indication of an old feces contamination and their presence on roof surfaces. They may appear after longer periods with a lack of rain", he concluded.

Faecal Coliform bacteria are a sub-group of total coliform bacteria. They appear in great quantities in the intestines and feces of humans and animals. The presence of faecal coliform in water sample often indicates recent faecal contamination, meaning that there is a greater risk that pathogens are present. For water to be considered as no risk to human health, the faecal coliform and E. coli counts/100mL should be zero (WHO, 2004).

The faecal coliform levels rainwater harvested from also showed varied results (Table 4.9). While rainwater harvested from the sky (SKY) showed no count of faecal coliform, the rainwater harvested from roofs and rainwater stored in tanks showed higher counts of faecal coliform far higher than the prescribed count by the WHO water quality guideline value of 0 counts per 100 ml. The higher counts of faecal coliform may be birds, which defecate on the roof catchment and dust that is washed by rain during the rainy season into the storage together with the harvested rainwater. The study also revealed that the sources of faecal coliform to the storage tanks was due to the fact that most of the domestic tanks that were used to store harvested rainwater were not covered or partially covered during most of the day. The Head of the Environmental Sanitation Department of the Assin South District Assembly indicated in an interview:

> *"The source of the faecal coliform could also be due to the way water was scooped from the tanks for domestic purposes. These people use any container they consider to be clean per their own judgment to fetch water from the tank. The most dangerous aspect is that many a time when they finish fetching the water, they leave the container on the floor only to attract dust and other contaminants. They use the same container in the subsequent time for fetching water again. I believe this is the main source of the faecal coliform"*, he quizzed.

The microbiological test was also conducted for Escherichia Coliform (*E. coli*). Escherichia Coliform is a sub-group of the faecal coliform group; this bacterium is harmless bacteria and is found in great quantities in the intestines of people and warm-

blooded animals. However, in other parts of the body, *E. coli* can cause serious disease, such as urinary tract infections, bacteraemia and meningitis. The presence of *E. coli* in water samples almost always indicate recent faecal contamination, meaning there is a greater risk that pathogens are present. Its presence in water or on the surfaces is used as an indicator of faecal contamination. The human health effects of *E. coli* causes diarrhea that ranges from mild and non-bloody to highly bloody and potentially fatal. The results from the research show that *E. coli* was present in rainwater harvested from roofs and storage facilities (Table 4.9). The reasons for the higher counts of   *E. coli* above the recommended level of the WHO was due to surface contamination and poor treatment of stored harvested rainwater.

The extent of pollution of the harvested rainwater as indicated in the research is a case to worry about as it has profound implications on the health of community members. This is because as indicated previously, rainwater is the main source of water for domestic purposes in the district. As indicated in the literature, the most serious and immediate health risk associated with roof-collected drinking-water is microbial contamination (McGranahan, 2007; Giuppon, et al., 2012; Owusu-Sekyere et al., 2014). While many of the micro-organisms found in roof-collected supplies are harmless, the safety of roof-collected rainwater for human consumption will depend on excluding or minimizing enteric pathogens. These organisms are introduced by contamination with faecal material deposited by animals such as birds, lizards and insects. The microbiological quality of drinking water is commonly assessed by testing for *Escherichia coli* (*E. coli*) as an indicator of faecal contamination.

4.7 The Trace Metal Properties of Harvested Rainwater in Assin South District

This section fulfils objective four of the thesis which seeks to examine trace metal content of harvested rainwater in Assin South District. Drinking water contamination with trace metals is one of the most important environmental issues as they are toxic even at low concentrations (Momodu and Anyakora, 2010). The literature indicates that there are about 35 metals that are of concern to human beings because of occupational or residential exposure. They include antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc (Ferner, 2001). Trace metals and especially heavy metals are well known to be toxic to human beings, where health risks of heavy metals include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Exposure to some metals, such as mercury and lead, may also cause development of autoimmunity, in which a person's immune system attacks its own cells. This can lead to joint diseases such as rheumatoid arthritis, and diseases of the kidneys, circulatory system, and nervous system. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Heavy metals may enter the human body via food, water, air, or absorption through the skin in agriculture, industrial, or residential settings (Roberts, 1999).

This research considered the average measurement of each trace metal parameter namely Salinity, Zinc, Total Iron, Manganese, Calcium, Magnesium, Arsenic, Chromium, Cyanide, Fluoride, Nitrite, Nitrate, Ammonia, Chloride, Phosphate, Sulfate, Total Hardness, Calcium Hardness, Magnesium Hardness, and Alkalinity (Table 4.8). Each

sample analyses was undertaken thrice and average recorded. The water quality test for the

harvested rainwater showed varied results. While some of the trace metals; Fluoride, Nitrite

Ammonia and Chloride among others were below the recommended WHO level acceptable

for domestic purposes, other trace metals such as Salinity, Total Iron, Manganese, Calcium

and Chromium were above the acceptable limit for quality domestic use prescribed by the

WHO.

Table 4.8 Trace Metal Analyses of Harvested Rainwater

PARAMETER	GHANA STANDARDS	UNIT	RESULTS		
			SKY	ROOF	TANK
Salinity	-	mg/l	1.7	4.1	5.6
Zinc	5	mg/l	0.11	0.06	0.13
Total Iron	0.3	mg/l	0.06	0.11	0.08
Manganese	0.1	mg/l	0.056	0.050	0.047
Calcium	-	mg/l	2.24	2.24	2.08
Magnesium	-	mg/l	0.194	0.680	0.388
Chromium	-	mg/l	0.02	0.01	0.07
Fluoride	1.5	mg/l	0.00	0.00	0.01
Nitrite	3	mg/l	0.22	0.03	0.02
Lead	10	mg/l	10.3	15.1	14.8
Ammonia	1.5	mg/l	0.52	1.06	0.86
Chloride	250	mg/l	7.25	5.75	7
Phosphate	-	mg/l	0.04	0.055	0.013
Sulfate	250	mg/l	-1	0	0
Total Hardness	500	mg/l	6.4	8.4	6.8
Calcium Hardness	200	mg/l	5.6	5.6	5.2
Magnesium Hardness	150	mg/l	0.8	2.8	1.6
Alkalinity	-	mg/l	5	35	35

The source of this Iron and Zinc for instance could be attributed to the corrugated iron sheets itself and atmospheric deposition. The corrugated iron sheets samples also had higher average Total Iron concentrations than rain water harvested directly from the sky. Given that corrugated iron sheets are composed of zinc and iron the higher concentration of Total Iron is not surprising.

What is worrying is that these trace metals may have consequences on human health when consumed in large quantities. For instance, Domingo (2007) has established that high concentrations of these metals can disrupt body functions and have pathogenic effects in human respiratory organs, kidney and skin and affect sexual and neurological development and functions. The allowed WHO limit for lead in drinking water is 10 ppb, however the results showed that the concentration of lead in the samples analyzed in this study exceeded the limit prescribed by the WHO guidelines for drinking-water quality. It has long been known that lead in drinking water is highly toxic. Exposure to lead is cumulative over time. High concentrations of lead in the body can cause death or permanent damage to the central nervous system, the brain, and kidneys. This damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain. Infants, children, pregnant women, and fetuses are more vulnerable to lead exposure than others because the lead is more easily absorbed into the sensitive tissue of actively growing bodies.

**4.8 Coping with Poor Quality of Harvested Rainwater**

Throughout history and in all societies water has occupied a central place in human endeavours. This stems from the fact that it is an inalienable part of the total human

existence (Bacho, 2001). The World Health Organization in 2008 estimated that approximately 1.3 billion people in the developing world lacked access to adequate quantities of clean water, and nearly 3 billion people were without adequate proper means of disposing of their faeces. WHO again estimates that about 10,000 people die every day from water and sanitation related diseases, and thousands more suffer from a range of debilitating illnesses (WHO, 2005). In all these the impact falls primarily on the poor especially those living in shacks and slums. Badly served by the formal sector, the people of the Assin South District have developed own, often inadequate arrangements to meet their water needs. This is typified by the long distances they have to trek to get this precious commodity. In the event of acute supplies, they end up relying on harvested rainwater and also paying high prices to water vendors for very small quantities of water. The research revealed that these water vendors in the district also rely on harvested rainwater they have stored in thanks for a longer period of time. The clear need for basic water and sanitation services for the poor assumes even greater significance when the linkages with other dimensions of poverty are considered. Water and sanitation related sicknesses put severe burdens on health services and keep children out of school.

The provision of water services in deprived rural settlements is a challenge faced by many countries in Sub-Sahara Africa (WHO, 2005). The rapid increase in population has meant that low income and rural settlements are growing much faster than formal and planned settlements. The lack of water supply services threatens not only the health and the environment of people in low income and rural areas, but also that of people living in urban areas (Kanton et al., 2010). According to Pinderhughes (2004) rural areas are the places where most of the human population in developing countries resides and where most of the

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resources consumption takes place, the Assin South District is no exception to this phenomenon. The research revealed that one of the environmental concerns raised by the respondents was contamination of water sources and its accompanying health impact. To cope with the poor water quality of harvested rainwater and the possible related diseases, respondents expressed various methods of treating water before use. These include boiling and the use of Naphthalene Balls (Canfer) before they utilize the harvested rainwater. The choice of water treatment is presented in Figure 4.6.
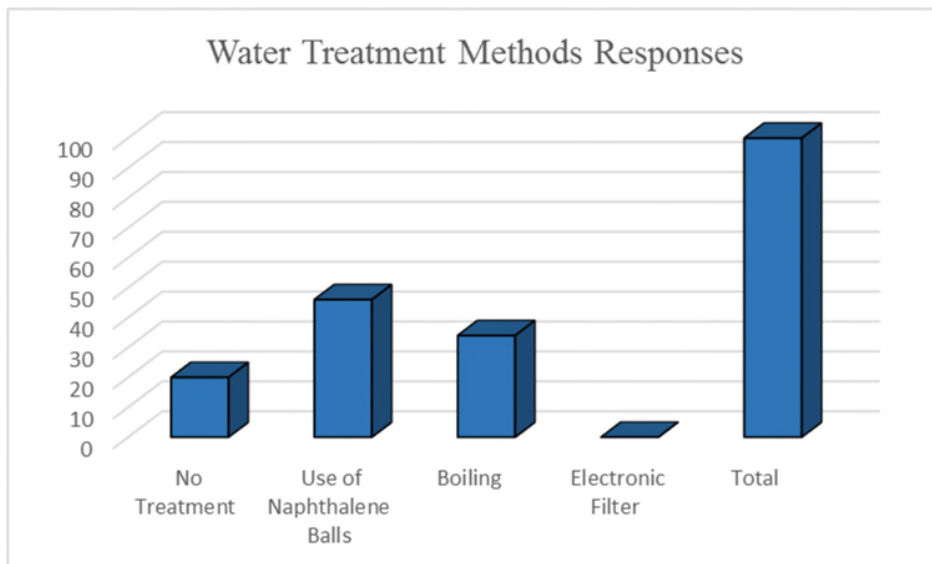
Figure 4.6 Water Treatment Methods

Figure 4.6 indicates that all the respondents took some form of steps to treat harvested rainwater before use. Whereas water treatment method were varied, the use of naphthalene balls was very popular across all respondents followed by boiling of water before use. The explanation given by respondents was that the use of naphthalene balls and boiling were simple and the cheapest but surest means of control. As one 56-year-old woman said in a

focus group discussion:

"Once you boil it, you are sure that the germs will die" she concluded.

The choice of water treatment method also varied across respondents' level of education. Respondents with higher level of education were conscious of the need to treat water before use, See Table 4.9.

Table 4.9 Water Treatment Method by Respondent's Level of Education (%)

Level of Education	Control Strategies			Total
	No Treatment	Use of Naph. Balls	Boiling	
No education	25	30	45	100
Basic education	15	45	40	100
Sec education	5	40	55	100
Tertiary education	2	33	65	100

The use of Naphthalene balls as water purification method seems to be very popular among the respondents irrespective of one's level of education, see Table 4.9. Whereas Naphthalene balls is noted for driving away ants and cockroaches, its efficacy as water purifier could be not ascertained by this research but what was clear was that it gave water sweet aroma.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The expression of water quality entails how the water resource is devoid of contamination and thus clean from any foreign or external elements that could compromise its physical, chemical or bacteriological compositions. The fear of utilization of such contaminated waters creates 'artificial' shortage or water scarcity. This chapter presents the summary of main findings, conclusion and recommendations of this research study.

5.2 Summary

This study was undertaken to examine the quality of harvested rain water in the Assin South District of the Central Region of Ghana. The research revealed poor quality of rainwater as one of the problems in the Assin South District. The trajectory of this condition has been well-mapped in the study: poor environmental quality in the community; erratic supply of potable water from the Small Town Supply System; growing population; disorganized estate development; insufficient storage infrastructure; and lack of initiatives from public and private sectors to invest in improved access to potable water supply. The difficulty in providing a level of service commensurate with demand is typically due to institutional, technical and financial constraints at national and local government levels and this is well articulated in literature. The study further showed that there were parts of the district received potable water from the small town water supply system managed by the Assin South District Assembly and Community Water Sanitation Agency only once a week or no water at all, users are forced to get their supply from rainwater harvesting which is

often of poor quality. The study also revealed that rainwater harvesting in the district consisted of collecting precipitation from rooftops and storing it in tanks. In terms of quality the research conducted three water quality test for three different parameters based on the objectives of the study. The first test covered the physico-chemical properties of the harvested rain water. The second test covered microbial levels of the harvested rain water where specifically, the level of coliform counts were determined. The third level of water quality test covered trace metal elements present in harvested rainwater within the study area. The results from all the tests showed that rooftops constituted particles and pathogens that contaminated water that falls through them. Based on the results from the water quality analysis, though not all parameters complied with Ghana Water Company Limited Water Quality Standards, there were evidence that the harvested rainwater harvested from the roofs, direct from the sky or stored in storage facilities were seriously contaminated posed health risk to the community. However rainwater harvested directly from the had no micro-biological contamination

5.3 Conclusion

The study interrogated the quality of rainwater harvested in the Assin South District of the Central Region of Ghana. The empirical evidence from the field unpacks some interesting revelations: it shows that in the absence of regular potable supply, the residents have devised an alternative means of getting access to water – rainwater harvesting. It identified a plethora of channels that harvested rainwater can be contaminated and the factors that determined the level of contamination. Again, the uncoordinated rainwater harvesting and the absence of specific laws and channels of approved rainwater harvesting and storage

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compelled the population to device their own rainwater harvesting and storage strategies. There are every indication that limited access to potable water supply is not going to take nose-dive in the district as demand for water for both economic and domestic activities was increasing. This means that there was the need to develop a definitive or even a more sustainable water supply systems that are environmentally friendly, socially acceptable and economically viable. Such a policy must seek to integrate all aspects, elements and stakeholders.

5.4 Recommendation

Based on the findings of the research, the following recommendations are made:

1. There is the need for intensive public education by the Community Water and Sanitation Agency and other allied agencies on how harvested rainwater should be stored and secured for human consumption. The public education will help consumers of rainwater harvested maintain clean storage tanks, clean filters, and rooftops. As part of the public education process consumers need to be advised not to harvest the first rainfall of the season since it may be seriously contaminated. A first rain diverter may be installed to ensure better quality from the water stored in tanks. From the results of the water quality analysis, samples collected in between rainy days had higher quality than samples taken from a precipitation event after several days of no rain.

2. Rainwater system owners should ensure water safety by conducting periodic water quality test to avoid any contamination. They must collect samples on

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regular bases and sent them to either the Ghana Water Company Limited, Center for Scientific and Industrial Research or Community Water and Sanitation Agency for laboratory examination.

3. It is recommended that owners of household rainwater harvesting system could mount water filters on the inlet and outlet pipes to filter harvested rainwater on two levels to eliminate any contamination.

4. It also recommended that there should be continuous water quality monitoring by both state and private agencies concern with and connected to water supply issues in order to prevent any health threatening diseases. In this adding some disinfecting agents such as chlorine might help in reducing the risk of biological contamination. This because the study revealed drinking water contamination with trace metals is one of the most important health issues as they are toxic even at low concentrations. Trace metals and especially heavy metals are well known to be toxic to human beings, where health risks of heavy metals include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death.

5. It is finally recommended that there should be a legislation and more investment by government to incorporate RWH system into building plans to improve access and quality. The study revealed that although some attempts have been made by CWSA to provide potable water in the Northern, Upper East and Upper West regions.

Intensive rainwater harvesting in the country could go a long way to solve the annual flooding. Although the Republic of Ghana could boast of rainwater harvesting policy much success have not been chalked. This is attributed to the fact that such policies and program lack local participation and initiatives. The paper is of the view that future policy interventions should actively involve the full participation of the community members if any achievements are to be made.

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APPENDICES

Appendix 1

The laboratory set for micro biological analyses for rainwater in laboratory of

Ghana Water Company Limited, Cape Coast.

Appendix 2

The Researcher in the laboratory of Ghana Water Company Limited.

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Appendix 3

QUESTIONNAIRE FOR HOUSEHOLDS IN ASSIN SOUTH DISTRICT

PRACTICING RAINWATER HARVESTING

I am a student of the University for Development Studies pursuing Masters of Philosophy program in Development Studies. As a requirement for the award of the degree, I am to undertake a research work in any discipline. In this regard I am researching into **Assessing the Quality of Household Harvested Rainwater in the Assin South District of the Central Region of Ghana.**

The study is strictly for academic purpose which will not identify any individual responses. I wish to assure you that any information provided for the purpose of this research will be treated with the utmost confidentiality. I appreciate in advance your consideration to participate in this research.

Thank you

SEX

Male ☐

Female ☐

AGE

15 – 20 ☐		36 – 40 ☐	
21 – 25 ☐		41 – 45 ☐	
26 – 30 ☐		46 – 50 ☐	
31– 35 ☐		51+ ☐	

RELIGION

Christian ☐   Traditional ☐

Moslem ☐   Others ☐

EDUCATION

1. What is your highest educational level? ………………………….

OCCUPATION

1. What is your occupation? ………………………………

SECTION A

Rainwater Harvesting and storage devices

1. Do you harvest rainfall? Yes ☐   No ☐

2. How do you harvest rainfall?
   a. Roof Catchment ☐   c. Rock Catchment ☐
   b. Direct from the sky ☐

3. Do you treat rainwater before use? Yes ☐   No ☐

4. How do you treat rainwater before use?
   a. Boiling ☐   b. Chlorination ☐
   c. Filtration ☐   d. Sedimentation ☐
   d. Others, specify…………………………………………………

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5. Where do you store harvested rainwater?

   a. Barrel ☐   b. Polythene ☐

   b. Metallic Tank ☐   d. Cement Tank ☐

6. What do you use the harvested rainwater for?

   a. Bathing ☐   c. Washing ☐   e. Gardening ☐

   b. Drinking ☐   d. Irrigation ☐   f. Cooking ☐

   g. Flushing Toilet ☐

7. What type of roof catchment surface do use for harvesting runoff?

   a. Aluminium Zinc ☐   c. Bamboo ☐

   b. Slate / Tiles ☐   d. Coated Zinc ☐

8. Is rainfall your main water source?

   a. Yes ☐   b. No ☐

9. Do you clean your catchment surface area regularly?

   a. Yes ☐   b. No ☐

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Probe: Do you clean the catchment surface?

Probe: How often do you clean the catchment surface?

Probe: How is the catchment surfaces cleaned?

Question: What do you use the harvested rainwater for?

Probe: Can you rate the uses in the order of preference?

Question: What are some of the challenges encountered harvesting rainwater?

Probe: how can such challenges be overcome?

Question: What are the problems associated with the uses of rainwater?

Probe: How can the problems be solved?

Question: What are your recommendations to improve rainwater harvesting in the district?

Probe: Who should implement the actions to improve rainwater harvesting in the district?

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