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City Development Corporation
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MASTER'S PROGRAMME IN URBAN MANAGEMENT AND DEVELOPMENT

(October 2009 – September 2010)

The Potential of Rain Water Harvesting in Ayigya, Kumasi, Ghana

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UMD 6 Report number:

Rotterdam, September 2010

Summary

Although, we live in a planet covered by water, more than 97 per cent of it is saltwater and nearly 2 per cent of it is in the form of ice and snows. This leaves less than 1 per cent to grow our crops and supply our drinking and bathing water for our household. It is pertinent to mention that 0.3 per cent of the fresh water is in lakes, rivers and wetlands. This amount includes water in plants, animals and in the atmosphere (Kingsolver, 2010). These figures illustrate universal challenges, ranging from the availability of water resources to its distribution to people.

Global statistics indicates that over a billion people live in a region of severe water stress and one of the targets of the Millennium Development Goals is to halve this number by 2015. However, this target seems daunting, considering the present water supply situation in Asia and Africa as many communities in these continents have never had access to piped water supply and sub-Saharan Africa has the world's worst level of water provision.

Ghana lies in the sub-Saharan region of Africa and nearly 40 per cent of the population are either un-served or underserved by piped water. The research area Ayigya lies in the south east district of Kumasi which is Ghana's second largest city and is 270 km away from capital city Accra. In this neighbourhood, nearly 91 per cent of the household have access to water by means of buying from water vendors/ neighbour sellers. And nearly 53 per cent of the household spends nearly US$0.22 to US$0.44 per day on water which is nearly 15 per cent of their income (Nyarko, Odai and Fosuhene, 2006).

This issue is precisely the stepping stone of this research and the main objective of this research is to explore the potential of rooftop Rain Water Harvesting at household level in order to improve the well-being of people in Ayigya. This research focuses on the techno-financial feasibility of adopting Rain Water Harvesting in the most cost-effective way at household level and employs survey and archival research strategies to collect data from the field. The data are analysed using both qualitative and quantitative methods in order to portray the ground reality of the research area.

The research reveals that Ghana Water Company Ltd. (GWCL) is entangled with new challenges in the supply of potable water in Kumasi due to the excessive demand for water. Although the rehabilitation work at Barikese Water Treatment Plant has increased its installed capacity to 90,720m^3/day it is still short of fulfilling the growing demands for water to meet population growth. The public private partnership (PPP) between GWCL and Aqua Vitens Rands Ltd. has failed to yield the desired results in these informal areas due to economic reasons. If we are to keep pace with population and economic growth, we need to identify and develop new supply sources and if required we need to look to the past.

In searching for solutions to this problem, the research looks at environmentally and economically sustainable factors with regard to the improvement of water provision in Ayigya. The research finding reveals that rooftop Rain Water Harvesting is a techno-financially viable option considering the perception of the various stakeholders and availability of various building components suitable for adopting the system at household level. Rain Water Harvesting is not a new approach. This system of collecting water from rain has been practiced by mankind for centuries. In the technological maze of the contemporary world we seem to have become ignorant to the fact that rainwater is our primary source of water in the hydrological cycle. The key is to catch it where it falls to quench the thirst of millions. The most important move towards ensuring adequate water and environmental conservation requires change in people's attitude and behaviour and it includes every one of us.

Key words: Rain Water Harvesting, ASPs, Incremental RWH, Ayigya, Kumasi

Acknowledgements

In writing this thesis, I would like to acknowledge the help of a number of individuals, to whom I am deeply indebted. Firstly, I would like to thank my supervisor Marc Jansen of Institute for Housing and Urban Development studies (IHS), Erasmus University, Rotterdam, for his valuable guidance and encouragement throughout the thesis period. I am also grateful to Nigel Browne, Cocky Adams and Ruud Frank also of IHS for their valuable inputs on various issues.

I thank Prof. K.B. Nyarko of Civil Engineering Department Kwameh Nkrumah University of Science and Technology (KNUST) and Mr. Timothy O. Nettey, Project Manager, GWCL, Ashanti region, Kumasi for their valuable insights on water supply situation in Kumasi. I would like to thank Kofi Apaiah-Simpson of Architecture Department of KNUST, Kumasi for his relentless help during my field work in Kumasi. Last but not least I wish to thank my friend Bryan O'donovan for his support and encouragement.

Further, I dedicate this academic work to my beloved father (Late) Mayengbam Ibotombi Singh, former Chief Engineer, Irrigation and Flood Control Department, Government of Manipur, India.

Dad, where ever you are, I miss you the most!

Dedicated to Dad!

My Dad receiving 'Rashtriya Ratna Award' in 2001 from Shri B.K. Patil, Union Minister of State for Finance, Government of India, for his excellent achievement and selfless service to India.

Abbreviations

ASP	Alternative Service Providers
AT	Appropriate Technology
CBO	Community Based Organization
CGI	Galvanised Iron Sheets
GWCL	Ghana Water Company Limited
GWSC	Ghana Water and Sewerage Corporation
DFID	Department for International Development
KNUST	Kwameh Nkrumah University of Science and Technology
MGD	Millennium Development Goal
MWRH	Ministry of Water Resources Works and Housing
NGO	Non-Governmental Organization
PSP	Private Sector Participation
PPP	Public Private Partnership
RWH	Rain Water Harvesting
SWE	Small Water Enterprises
WTP	Water Treatment Plant

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Chapter 1

1.1 Introduction

Water is vital to life and there is no known substitute to it. Our greatest dread is of having too little, too much or water that is too dirty. The amount of moisture on this planet has not changed since its inception and the water we get from rain today is the same as the water the dinosaurs drank millions of years ago. But will there be enough for every one of us is a question to be answered (Kingsolver, 2010). In the developing world, there is a scarcity of water in both urban and rural areas. Every year, unsafe water, coupled with a lack of basic sanitation, kills at least 1.6 million children under the age of five years – more than eight times the number of people who died in the Asian tsunami of 2004 (WHO and UNICEF, 2004).

Global statistics indicate that over one billion people have no access to clean drinking water and 2.4 billion, around 40 per cent of the world's population, lacks safe and hygienic sanitation (WHO & UNICEF, 2000). Further, UN-HABITAT (2003) states that out of the one billion people that have no access to safe drinking water, the majority lives in Africa and Asia and one of the targets of the Millennium Development Goals (MGD) is to halve this number by 2015. However, this challenge seems daunting considering the existing piped water supply systems in low income countries and high population growth in urban areas (Lee and Schwab, 2005). This statement is further supported by the UN-HABITAT statement that in most of the developing countries, the majority of low income households does not have access to piped water and rely on alternative sources (2006). Thus, in spite of great efforts over several decades, still about 1.2 billion people in developing countries lack access to safe drinking water.

The most prominent reason behind inadequacy of potable water supply is the excessive growth of demand. There are two key factors fuelling this increase. The first is the increase in demand due to the improvement in the per-capita income. The second aspect is the increasing concentration of population to urban centres. The increase in population has direct consequences on demand for water, which in turn requires high infrastructural cost in conveying water from remote locations for distribution in urban areas (Vairavamoorthy, Gorantiwar and Pathirana, 2008).

According to UN- HABITAT (2003), by 2015 more than 50 per cent of the world's population will reside in cities and by 2030 this figure is likely to increase to 60 per cent. As this scenario continues, the majority of developing countries are facing acute shortages of drinking water and sub-Saharan African countries have the world's worst water provisions. It is also predicted that Africa will face a large growth in population over the coming decades. As a result, approximately 210 million people in urban areas will need to be provided with water services (WHO&UNICEF, 2000). Consequently, the problem of distribution of sufficient water, especially to urban agglomerations, is a difficult challenge to overcome. Solutions to this problem should be looked for by considering technical, behavioural and regulatory means in order to achieve sustainability.

From a global perspective, even though we live on a planet covered by water, 97 per cent of it is saltwater and nearly 2 per cent is in the form of ice and snow. This leaves less than 1 per cent to grow crops and supply drinking and bathing water for households. The freshwater available in lakes, rivers and wet lands constitutes only 0.03 per cent and this includes water in plants, animals and the atmosphere (Kingsolver, 2010).

These figures demonstrate the global challenge in terms of the availability of water resources to its people. Moreover, the Inter-Governmental Panel on Climate Change (IPCC) predicts that climate change will adversely affect freshwater availability in large basins. Climate change will also affect precipitation patterns and lead to the disappearance of glaciers, which will affect water availability for human consumption and nearly 250 million people will be exposed to increased water stress (Huysman, 2010). Hence the search for alternative, cheap and renewable source is paramount if we to quench the thirst of millions. In this regard, this research looks at techno-financial feasibility of adopting rooftop Rain Water Harvesting (RWH) at household level to improve the water provision in the research area.

1.2 The Research Area, Ayigya, Kumasi, Ghana

Ghana lies on the Gulf of Guinea, between Ivory Coast to the west, Togo to the east and Burkina Faso to the north. Climatically it is situated in the sub-Saharan region of Africa and has a total area of 338,540 km^2. The estimated population is around 22.5 million with 58 per cent living in rural areas and the remaining 42 per cent in urban areas (Awuah, Nyarko and Owusu, 2009). When Ghana became independent in 1957, it had a relatively competent civil service and reasonably developed infrastructure with adequate foreign exchange (Rakodi, 1996 as cited by Martins and Sluiter, 1999).

Figure 1: Map of Ghana

Source: *mapsworldwide.com*

Ghana's programme of decentralisation and democratisation during the late 1980s and early 1990s failed to achieve the devolution objective envisaged by the country's laws and the process remains incomplete (Devas and Korboe, 2000). Aside from this, government mismanagement and political conflicts in the 1970s and the 1990s had a negative impact on its economy and infrastructure. During this period, the infrastructure of major cities deteriorated considerably and one such city, which was affected and is now recovering, is Kumasi (KPMG, 2008)

Kumasi is the second-largest city of Ghana and it contributes significantly to the country's economic growth. As the city is located centrally in the Ashanti region, it forms an important transport hub for both domestic and international traffic. The Ashanti region comprises of 21 districts and has a total area of 24,389 km^2. Kumasi is the regional capital and is situated 270 km northwest of the capital city Accra. Due to its strategic location and vibrant economy, the city is considered as the commercial capital of Ghana. The Kateja Market, which is the largest open-area market in West Africa, is located in the heart of the city, contributing extensively to the regional economy. Kumasi had the highest population in the Ashanti region with 1.6 million in 2006 (KPMG, 2008) a figure which is collaborated by the Population Census Report of Ghana.

Table 1: Population of Kumasi

Area/year	1948	1960	1970	1984	2000	*2006
Kumasi	81,870	218,172	346,336	487,504	1,170,270	1,625,180
Ashanti	1,109,130	1,481,698	2,090,100	2,948,161	3,612,950	3,899,227
Nation	-	9,726,320	9,632,000	12,296,081	18,912,079	22,225,625

*Source: Population Census Reports (1948, 1960, 1970, 1984 and 2000) * Projected*

As the city is expanding rapidly in all directions due to population growth, the present water infrastructure fails to meet the growth of the city's demand, which in turn has led to scarcity of water in peripheral areas. Although piped water is available in most parts of the city from the Ghana Water and Sewerage Corporation (GWSC), the service suffers from intermittency and low pressure. The majority of low income households in Kumasi depend on alternative supply sources as they do not have piped water connections (UN-HABITAT, 2006). Nearly 40 per cent of the population, which are either under or un-served by piped water, depends on alternative sources (Nyarko, 2008). These alternative sources comprise of domestic vendors, neighbour sellers, water sachet sellers, cart operators, tanker operators who have moved in as alternative service providers (ASPs) to cater for the under and un-served population. Further, all these operators depend on the utilities for their primary supplies and form an intermediary supply chain between the end-users and water utilities (Sarpong and Abrampah, 2006). A typical neighbourhood where ASPs have become prominent in the supply of water is Ayigya. This area is the main focus of this thesis.

Ayigya neighbourhood itself lies in the south-eastern part of Kumasi with a population of 30,000 and is about 5.7 km from the city centre. The infrastructure in this neighbourhood is very poor as there is no proper drainage or sewerage system. Most of the roads are unpaved, which leads to heavy erosion during the wet season, and existing infrastructures, including the water supply and sanitation, are sub-standard (Plaza, 2009). There are very few piped water connections from urban water utilities.

1.3 Problem Statement

Available data show that in Ghana, about 30 per cent of its nearly 18.3 million people have no access to potable water. Even those 70 per cent who have access to potable water depend on informal and often irregular sources (Sarpong & Abrampah, 2006). According to Ofosu (2004), currently Ghana Water Company Limited (GWCL) operates 86 urban water supply systems throughout the country. The total installed capacity is around 737,000 m^3 /day; however, average daily production is 599,000 m^3 /day while the present urban demand is around 995,000m^3/day (as cited Nyarko, 2008). This figure shows a huge shortage in supply, and consequently, a high percentage of the population depends on alternative means for survival. Ghana's nearly 40 per cent urban population which is un-served or under-served depend on informal supply and these alternative service providers in turn depend on their own sources of water or on piped water supply from GWCL. Moreover, their price and water quality are not regulated (Nyarko, 2008).

However, water is essential to humans for survival. To survive, humans need one or two litres of drinking water per person per day and a minimum of 20 to 50 litres are required for food preparation, bathing and general hygiene (UN-Habitat, 1989). Where GWCL has failed to deliver, the ASPs have sprung up as alternative providers to close the gap between the demand and supply of water. The ASPs consist of water vendors, neighbour sellers and independent producers and sell water at a comparatively high price. This price could be up to ten times that of water utilities and this has a direct impact on the low income households who cannot access government subsidies and economics of scale (Nyarko, 2008). The majority of households in Ayigya do not have piped water connections and nearly 91 per cent of them have access to water by means of buying from water vendors/neighbour sellers (Nyarko, Odai and Fosuhene, 2006).

The inability of governments to maintain and extend distribution systems to the urban poor in developing countries is mainly due to the shortage of funds, as these countries are among the poorest in the world with more than 80 per cent of the funds primarily coming from external loans or grants (UN-Habitat, 1989). This problem is further aggravated by a surge in demand due to factors of population growth and increasing concentration of population in urban centres.

Providing water services to this neighbourhood is a challenging task for water service providers and policy-makers, as they are faced with physical, technical and financial limitations coupled with high population growth. This has resulted in a large gap between the demand for, and supply of, water in this neighbourhood. In order to close down this gap, water vendors and neighbour sellers have sprung up to cater the un-served population as Alternative Service Providers (ASPs).

The above facts highlight the inability to provide adequate safe drinking water by the formal sector, whereas the informal sector, while characterized by high prices and dubious quality, remains indispensable to the vast majority of the population.

To illustrate this, 53 per cent of households in Ayigya spend 15 per cent of their daily income on water and the average household income is 2,000 Cedis (US$ 2.22) (Nyarko *et al.*, 2006). Given the scenario described above, it is increasingly clear that conventional models of service delivery are unaffordable and incapable of meeting the demands of the new urban environment. With this in mind, this research looks at the possibility of supplementing water-provision on a smaller scale, such as at household level, by means of roof-top Rain Water Harvesting (RWH). This approach is adopted with a common objective: the increased supply of water at an affordable price.

1.4 Main Objective of the Study and Research Questions

The main objective of this research is to examine the issues related to potable water provision in Ayigya, and to identify the problems and potential solutions related to it, in order to improve the well-being of people in Ayigya.

Specific Objectives

The specific objectives of this research can be summarized as follows:

1. To evaluate the service through municipal piped water supply with a view to understand its performance, in terms of quality, reliability and price;
2. To evaluate the service through ASPs with a view to understand its performance, in terms of quality, reliability and price;
3. To identify the potential of Rain Water Harvesting (RWH) as a supplementary alternative source, in order to alleviate water scarcity;
4. To recommend possible integrated strategies that the Government can use to close the gap between the supply and demand of potable water through RWH.

Research Questions

The specific research questions to be asked in the course of this study are:

1. How the government piped (water) supply is organized in Ayigya, Kumasi?
   - Who are the stakeholders?
   - In how far does Ayigya population depend on this piped supply?
   - What is the actual cost & quality of water?

2. How is the supply system organized by ASPs in Ayigya, Kumasi?
   - Who are the stakeholders?
   - What is the size of the population which depends on ASPs?
   - What is the actual cost & quality of water?

3. What is the technical and financial feasibility of adopting household Rain Water Harvesting (RWH) as a supplementary source of water for the affected population?
   - Which appropriate technology should be adopted in order for RWH to be sustainable?

1.5 Scope of the Research

While the issue of water-provision is a fascinating and many-facetted subject, it has proven necessary to limit the scope of this study, in order to accurately portray and analyse the problems as they are, while at the same time providing potential solutions. In terms of water provision, this thesis deals with the potential of RWH. While the formal sector and informal sector need to be described, in order to paint a full picture of water-provision in the areas concerned, the study will focus mainly on potential of RWH. Moreover, the rainwater harvesting methods discussed in the following pages focus only on roof catchment, which is based more on the individual and community efforts. Although, large-scale and high-tech Rain Water Harvesting does exist at higher infrastructural cost, this research is more interested in the low-cost rooftop RWH at household level for supplementing the supply of water.

1.6 Thesis Structure

This thesis has five chapters and the contents are highlighted

Chapter 1: Provides the introduction to the topic along with the research area. The ensuing section leads to problem statement, research objective, research questions and scope of the research.

Chapter 2: (Literature Review) provides the theoretical foundations and concepts related to the chosen thesis topic. This chapter starts with a discussion on general water supply and various approaches and their limitations in providing water to the urban poor. The ensuing sections look at the concept of sustainability and demand. The conceptual framework, in the last section, illustrates the relationship between different components of water supply and sanitation and the potential role of RWH in the whole system and its sustainability.

Chapter 3: (Research Methodology) provides a brief description of the research area and then proceeds with research design and different methodologies employed to gather data and other information needed to conduct an appropriate analysis based on the objectives and research questions in Chapter 1. The other sections of this chapter explain the analytical process to be used, illustrated by an analytical framework, and the relevant variables and indicators, which are rooted in the research questions of the study. The data sources for each of the variables and indicators are also presented.

Chapter 4 (Research finding and analysis) discusses the main findings and analysis from the secondary and primary data based on the research questions. Further, it provides a clear picture of the research area in the chosen topic to make suitable and appropriate recommendations.

Chapter 5: (Conclusion) offers a conclusion and recommendations of the study.

Chapter 2: Literature Review

Chapter one introduced both the general aim and specific objectives of this research with research problem and background to the research. As mentioned in chapter one, the research looks at techno-financial feasibility of adopting rooftop rain water harvesting using appropriate technology as a supplementary source of water. The key purpose of this research is to develop a sustainable independent water supply approach in overcoming the scarcity of water through RWH at household level. However to understand the whole system, formal and informal water supply approaches need to be described. Therefore, the literature review is focused around three core concepts with more detailed sub-groups:

1. **Supply (in sub-chapter 2.1)**
   - General water distribution networks (2.1.1).
   - The institutional approach to water supply and its limitations (2.1.2).
   - The informal approach to water supply and its limitations (2.1.3).

2. **Sustainability (in sub-chapter 2.2)**
   - Sustainable development (2.2.1).
   - Appropriate technology (2.2.2).
   - Rain water harvesting (2.2.3).

3. **Demand (in sub-chapter 2.3)**
   - Does the community want the facilities? (2.3.1).
   - Sanitation habits (2.3.2).
   - Health aspects of water supply and sanitation (2.3.3).
   - Demand for water (2.3.4).
   - Willingness to pay (2.3.5).
   - Affordability (2.3.6).

In the following section, researcher will provide an overview of the components of a typical water distribution network, before highlighting the different approaches to water management.

2.1 Supply

As pointed out above, there are three main issues surrounding water distribution to be looked at in this section, beginning with a general look at water distribution networks, before examining the respective processes and limitations of both the formal and informal approaches to water supply.

2.1.1 General Water Distribution Networks

A typical water supply system includes a source intake, a raw water transmission main, a treatment plant, a treated water transmission main, and a water distribution network (World Bank, 1986). Of these components, the distribution network is usually the most expensive, representing more than half the total cost. It is also the most difficult component to design. There are four types of distribution systems. These are: single pipe, branched, looped and combinations of these. For all of the different types of networks, the design approach is basically the same. The approach can be broken down into four steps: layout, calculation of design flows, calculation of pressures, and the selection of pipe diameters.

The water utilities in many developing countries suffer from aged distribution systems (Ciuche, 2005). The problem is further compounded by inappropriate pipe sizes being used in the distribution system (which in turn causes intermittency and low pressure) and their inability to upgrade the system due to shortage of funds. The problem is further aggravated by corrosion of the pipes and improper and low quality fittings, causing leakage. A good distribution system on average has a leakage of 10 to 20 per cent; however this percentage could be as high as 40 to 80 per cent in a badly maintained system, especially in developing countries (Brilhante, 2010).

While the infrastructural aspects of water distribution systems are integral to their effectiveness, the way the system is managed and administered has a significant impact on the final product. In this regard, the following sections will highlight the varying methods of water management, as well as their respective advantages and disadvantages.

2.1.2 The Institutional Approach to Water and its Limitations

The monopoly utilities such as water supply and sewerage are generally control by the government in many countries. The reason behind this trend is because of large economics of scale involved in the system and the nature of infrastructure required which seeks for a single entity to operate effectively. Other reasons include the low capacity to pay for the service and realisation of health benefits to the people it served (Ndezi, 2004). Due to afore mentioned reasons, in many countries, the urban utilities have been traditionally managed by the government until the private sector participation process started a few decades ago. Njiru (2002) posit that the urban utilities in many Sub- Saharan counties were under the direct control of government till the late 1980s (as cited by Ndezi, 2004).

Challenges of Public Water Services to Serve the Urban Poor

The main aim of the urban utilities in many countries is to provide service to help all sections people irrespective of rich or poor. But unfortunately urban poor are not generally connected to the piped water system from the utility providers hence this approach failed to meet the intended goal to help to urban poor. Besides this, due to poor performance, many water utilities are faced with insufficient finance to fund for expansion, rehabilitation and regular maintenance works. All these factors lead to deterioration of the asset and affects the ability of public utilities to manage the existing water supply system and provide water connections to urban poor (Ndezi, 2004). The growth in urban population has an impact on urban utilities and many of them are incapable meeting the growing water demand (Mugabi, Kayaga and Njiru, 2006).

Approaches under Private Sector Participation

Private Sector Participation (PSP) can be defined as bringing the private sector in public domain. Brilhante and Frank (2009) posit that the spectrum of PSP includes multiple forms of service contracts, joint ventures, private sector technical advisor ship, management, lease, Build Operate Transfer (BOT), concessions contracts and full divestitures. Further, Public- Private Partnerships (PPP) is defined as private sector involvement where both public and private sector share the risk related to the investment (van Dijk, 2006).

There major reasons for many governments of developing countries to look for PSP in urban water provisions can be classified as both external and internal factors. The external factor is related to the wider political system and level of decentralisation, whereas the internal factor includes the incapacity of government authorities to keep pace with the growing demand due to rapid urbanisation (Ndezi, 2004).

Limitations of PSP Approaches to Serve the Urban Poor

The private sector participation in provision of urban services have been controversial although this approach is capable of raising enormous amount of fund to meet the required capital for improvement in quality of services in cities. This approach entails a more commercial approach thereby lead to withdrawal of subsidies, increase in water tariff, increase in number of disconnected customers due to non-payment of bill and reluctance to connect less profitable consumers (Brook & Irwin, 2003). Due to these reasons many section of people of have raised their concern about the impact of this approach especially on the poor. This clearly shows the commercial bias of this approach in providing basic services to low income areas

Community Management Approaches

Community management is an approach that makes best use of resources available within the community with support from government agencies, NGOs, CBOs, the private sector and other communities (Evans and Appleton, 1993). In this type of approach, the users have a voice, as well as a choice of technology, type of service, service providers, financing arrangement and management systems, in exchange for making contributions which are usually in cash or in kind (UN-HABITAT, 2003).

Such approaches often seek to engage community members from the beginning of the service delivery process in order to build community ownership and strengthen their capacity to manage services (Rahardjo and O'Brien, 1994). They are driven by the understanding that many communities are willing and able to develop their own water supply rather than wait for government provision, often because their costs will fall if they work together to improve on existing provision. Community-managed water systems vary from relatively unsophisticated systems such as large water tanks from which the inhabitants can collect water, to piped water supplies being supplied through water utilities or discrete independent water systems (UN-HABITAT, 2003).

In spite of these different models used by formal approaches, the water utilities are unable to cater for the growing demand of the population. As a result, a large chunk of the population, which is un-served by these utilities, relies on alternative sources. The following section highlights the informal approach and their constraints.

2.1.3 The Informal Approach Water Supply and its Limitations

In many urban areas, due to absence of water utilities, many informal independent water providers have come in to fill the gap. These alternative service providers accounts up to 70 per cent in some countries and offers a varieties of services customised according to local demand (World Bank, 2001).

Small Water Enterprises

Small Water Enterprises (SWEs) are informal private operators operating at a small scale in providing water to un-served and under-served population left by water utilities. SWEs comprises of various type of water vendors, neighbour seller and water tankers who collect water from the source and delivered to water vendors or to individual customers. Generally SWEs gets there supply from their own source or from urban utilities and sell directly to customers who come to them to purchase water (Sarpong and Abrampah, 2000). They are well placed according to Ndezi (2004) in providing informal water supply to informal urban settlements. However, Nyarko (2008) argues that they are characterised with high cost compare to urban water utilities and dubious water quality.

Constraints of Small Water Enterprises

The above section described the importance of SWEs in serving the un-served poor in urban settlement. However, despite of their acknowledged presence in urban water delivery, SWEs face number of constraints from various angles in their functioning. Some of the major constraints faced by them are supply constraints; price constraints, water quality constraints, financial constraints, lack of technical and managerial skills and social recognition (Sarpong and Abrampah, 2006). It is argued that these factors undermine their potential to make a significant contribution to provision of good affordable water services to their customers (Njiru, 2003). It is further argued that Water vendor typically operates outside the legal frameworks. While household water resale may not be illegal, but technically speaking households engaging in such a trade should be commercial water vendors and higher volumetric tariffs should be applied (Kjellen and Mcgranahan, 2006).

The above facts, established the inherent limitations of both the approaches in providing water supply to urban poor. The formal approach including the effort of privatisation in public utilities has yielded a meagre effect on the urban poor. This is mainly due to reluctance of private sector in expanding water services in low income settlements due to commercial reasons. This inability to provide water supply to low income zones leads to formation of informal alternative service providers to cater the demand of un-served and under-served population. For the low income group, as there are no other means, they have to depend on informal sector to avail their basic water demand by paying a higher price.

However, this informal approach too as discussed earlier has its own limitations. These limitations create an opportunity to explore for alternative source of water which could quench the thirst of un-served populations. Further, in the following section the issue of sustainability is look on a wider perspective to understand the relevance of rain water harvesting in reserving our scarce resources for future generations.

2.1 Sustainability

2.2.1 Sustainable Development

The 'Brundtland Commission' defines **sustainable development** as 'meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*'* (UNCED 1987:43).

Sustainable Development can be referred to as conserving our natural environment for our future generation (Blewitt, 2008). It is understood that our activities have an impact on our environment. Any human activity which is associated with depletion of our scares could have a negative impact on socio-economic conditions for our future generation. Further, it also decreases the capacity of our ecosystem to absorb the impact.

Therefore, a potential change in our human behaviour and lifestyle can have an impact on our resources and environment. This is because our activities and lifestyle determines consumption patterns which in turn have an effect on our environment and resources. (Plaza, 2009)

If we look at the amount of water we extract from groundwater for use, it has an effect on our environment as well as our resources apart from the energy used in pumping out the source. According to (Taylor, 2007) around 80 per cent of the industry's energy use in UK is for pumping and about half the carbon emitted by the industry comes from the clean water side and domestic hot water use excluding central heating emits around 30 million tonnes of carbon dioxide per year. That is around 5 per cent of the UK's total annual greenhouse gas emissions. Similarly treatment of wastewater needs huge investment and energy and therefore there is a need to reduce the flow and this demand for better water efficiency and reduction in the amount of surface run-off getting into the sewerage system. This shows that our behaviour and living style has a close relationship with efficient use of scarce resources.

According to Faulkner and Albertson (1986) Sustainable living is a decision for applying sustainability to lifestyle fundamentally. Sustainability itself is defined as meeting present ecological, societal and economic needs without compromising these factors for future generations.

Therefore sustainable development is crucial to sustainable living and practices which in turn embraces the development of appropriate technology which is the base of sustainable living practices.

2.2.2 Appropriate Technology (AT)

The cultural, social and political life has been influenced by the change in economic activities brought about by the technological revolution. Schumacher–the pioneer of the appropriate technology movement–has emphasized that technology is integral to the existence of human being. It is essential for the technology to be responsive to the context in terms of psychological and biophysical development, so as to achieve positive results for the community (Willoughby, 1990).

The basic instinct for survival and propagation has equipped the human beings to adapt to his changing environs with time. Innovation and adaptation of an appropriate technology is but quite natural for human beings as a species to create a niche in the ecological context.

Species are understood by their adapting qualities to its surrounding in ecology. In the similar fashion, a technology which is adopted to suit a particular circumstance is a technological niche and can be contextualized as psychological and biophysical development. Since early times, mankind has been constantly developing different ways and means to suit the basic requirement according to its surrounding conditions, whether it may be the building of a shelter or the collection of water from rainfall. The latter is known nowadays as rain water harvesting. It is a simple way of collecting rainwater and storing it for later use and the following section explains the concept and the potential of rain water.

2.2.3 Rain Water Harvesting (RWH)

Collection and storage of rain water is a method of intercepting water from the hydrological cycle to ensure supply of water during lean periods. This is known as rainwater harvesting.

Since water is essential for sustenance in human habitats and for agriculture, rainwater harvesting has become an integral feature of farmlands and urban habitats. The requirements of water quantity, quality, and duration and time vary for agriculture and for human needs. Catchments and storage for agriculture are based on natural watersheds in the topography on a regional scale. Whereas for individual human habitats, roofs are catchments and storage is in the tanks in or near the house. Roofs are preferred as catchments to ground surface catchments so as to ensure the appropriate quality of the water (World Bank, 1986).

Further according to World Bank (1986) an accurate method of calculating a rain water tank size requires an analysis of data using mass curve technique. During the collection process, some rainwater will be lost and this amount is represented by a fraction called runoff coefficient and a metal roof with good gutters has a runoff coefficient of 0.9 whereas a metal roof with poor gutter has a runoff coefficient of 0.8. The horizontal roof area is the catchment area and thus the average yearly supply from rainfall can be calculated by-

Supply = catchment area x runoff coefficient x average annual rainfall.

On the economical aspect, small scale RWH does not involve the existing water right. And it has become one of the economical and practical measures for providing supplementary water supplies with its easy system installation. It can be a supplementary water source in urbanized regions for miscellaneous household uses such as toilet flushing, lawn watering, landscape and ecological pools (Handia, Tembo, Mwiindwa, 2003). In many developing countries, it even serves as a major water supply source (Thomas, 1998). Other than storing rain water for later uses, it is also capable of providing some detention capacity for flood attenuations in some regions (Kumar, Singh and Sharma, 2005). Rainwater harvesting system has been regarded as a sound strategy of alternative water sources for increasing water supply capacities (Motsi, Chuma and Mukamuri, 2004).

In the technological maze of the contemporary world we seem to have become ignorant to the fact that rainwater is our primary source of water in the hydrological cycle. This has led us to become over dependant on the secondary sources of water such as rivers, lake and ground water which also require rain water for their recharge. The key is to catch it where it falls, this concept has been the basis of rainwater harvesting since centuries. Although new techniques are being developed for collection, storage and recharge of ground water but the basic concept still remains the same.

Water harvesting means to understand and appreciate the value of rain, and to make optimum use of it at the place where it falls. The collection of rain water can be undertaken through a variety of ways, such as:

1. Collecting runoff from rooftops;
2. Collecting runoff from local catchments;
3. Capturing seasonal floodwaters from local streams;
4. Conserving water through watershed management.

These techniques can serve the following purposes:

1. Provide drinking water;
2. Provide irrigation water;
3. Increase groundwater recharge;
4. Reduce storm water discharges, urban floods and overloading of sewage treatment plants.

Presented above is the concept and theory of how RWH should work. However, this is not an untested idea. There have been pilot projects in different parts of the world where water scarcity is a problem. In the following sections are some examples where rain water harvesting has been used to a degree of success.

Box 1: A Rainwater from Roof Catchment: a Classic Success Story in North-East Thailand

According to World Bank (1986) only 10 per cent of the Thailand's rural population had access to safe water and only 25 per cent of the Thai population had piped water system. Rest of the population depends on other sources of water supply of doubtful quality. This was the outcome of as assessment of WHO in 1978.

The Population and Community Development Association, a non-government organization launched a household roof rainwater catchment project in the driest region of Thailand, the North eastern

Thailand. This was a self-help programme where the villagers themselves built the rain water storage tanks. Earlier attempts to provide safe drinking water to the population using hand pumps, piped water supply and wells had failed due to lack of technical know-how for their maintenance. Water is drawn from open ponds, rivers, reservoirs and wells where improved water supply systems are not available. This water is non-potable and also in short supply. Thus there is a critical need for rainwater storage system in this region.

The roof catchment technology is not complex and the villagers are able to maintain the system. They were already familiar with this technology except that their storage capacity was limited, thus enough water was not available for the dry season. The agency provided the required input by introducing an improved technology using large water tanks. An assessment study showed that the bamboo reinforced concrete tank was found to be the most acceptable technology, as it had the low cost per cubic storage capacity and it was simple to build from locally available materials.

The average cost of the water tank was 270 U.S. dollars. The soft loan allows the household to repay 200 dollars it over 20 months, only the balance 70 dollars have to be resourced externally. 60 per cent of the loan has to be paid before loan is given to the next group of villagers. This simple method of financial arrangement involving a revolving loan fund, labour input by the villagers makes this scheme affordable.

Since labour inputs are provided by the people, it calls for one household helping the other in the construction of the tanks. This has led to better community relationship and gives the community a sense of belonging and pride. Constructing the water tanks themselves trains the community for their upkeep, thus cutting maintenance costs. Such community efforts are one of the main reasons for acceptance of projects by the people.

The success of this programme has been due to the cordial relationship between the people and the organization. The population and community development association has won the trust of the population by helping more than 16,000 villages of this region in various activities. This was one of the main reasons for the success of roof rainwater catchment programme. In the end, there are four factors for successfulness of this program, which are:

1. There is critical need of RWH;
2. The use of appropriate technology;
3. Affordability of the program; and
4. The community effort to make this programme a success.

Box 2: Roof Rainwater Harvesting Systems for Households Water Supply in Jordan

The most important challenge faced by Jordan environmentally is scarcity of water. The current water supply is unable to meet the growing demand of the country. According to Abdulla & Al- Shareef (2009) there are no doubts that the rainwater runoff from the roofs of the buildings can help to mitigate the shortfall in the demand for water in Jordan, which has been experiencing a severe shortage of water. The concept of rainwater harvesting has not been quite popular although it has been there since quite some time. The fact that rainwater water harvesting can be a possible source of water supply has been recognized through samples from roof systems. Rainwater harvesting from residential roofs can help the authorities to tide over this crises of short fall in water supplies, as studies have shown that rainwater collected from roofs was potable, and need be used only for secondary purposes.

Apart from illustrating the potential of rainwater harvesting in two different countries with different climatic conditions, it is also equally important to know whether the community wants the facilities or not and to understand this better, the following section posits this very concept.

2.3 Demand

2.3.1 Does the Community Want the Facilities

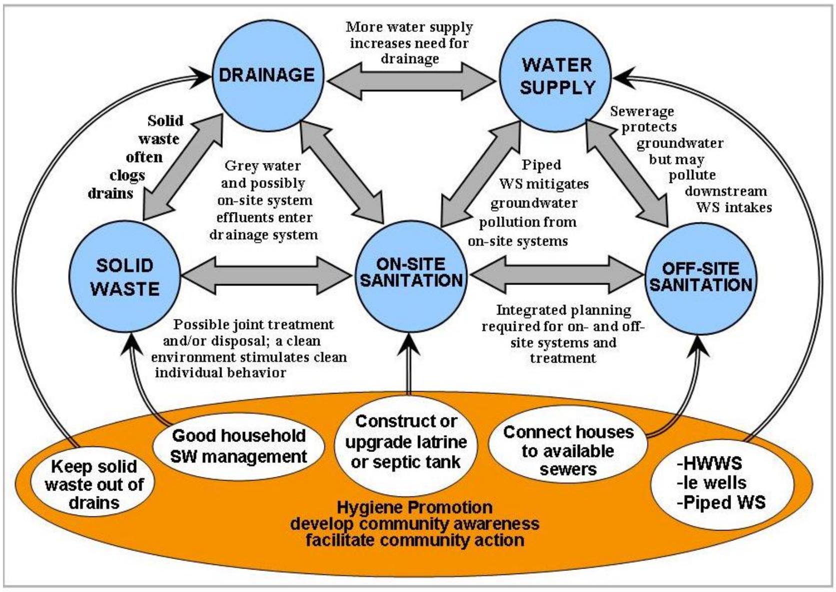
The most important *question* is "Does the community want the facilities?" The community sometimes simply does not wish to have the proposed improvements or has other priorities. They may be so opposed that the possibility of user participation can be ruled out from the initial stage.

In such case according to World Bank (1986), the implementing agency can adopt two alternatives. Firstly, it can drop the idea and move on to a more receptive community, or secondly, it can mount a promotional campaign aimed at altering the attitudes of people in the unreceptive community. In determining the degree to which user participation is possible in a project, a number of vital questions need to be answered:

1. How interested are the potential users in the proposed facilities? Are they anxious to be included in the project, or only mildly interested? Did the interest come from the whole community or from a few politically visible individuals? The answers to these questions will determine what effort will be needed to promote the technology and the project.
2. Are the users able and willing to pay part of the costs? In many rural villages in poorer countries, people have no cash income and are unable to pay. The ability to pay needs to be *accurately* assessed. If the people are asked to contribute more than they are able, the project may be seriously jeopardized.
3. Is the community willing to contribute materials and/or labour to the construction of the facilities? Are they informed of the continuing cost of operation and maintenance? Again, this needs to be accurately assessed.
4. How much spare time do the users have to work on the project? Can they combine their regular routine with working on the project? Are they too tired after a day's work?
5. Do the people possess any skills which could be used in the project? Are any of them capable and willing to be trained as artisans, technicians or better managers of household water supply and sanitation?
6. Is the proposed technology acceptable to the users? Is it compatible with their social and cultural beliefs and views? Are there any obvious design changes or adaptations which would make it more acceptable?

Generally a part of understanding what the community wants, when we talk about water supply system, we tend to forget the other side of the coin i.e., how and where the waste water could be discharged safely without contaminating the surface water sources and ground water sources. The amount water supply to household is partly consumed and partly discharged in the form of waste water and there should be an adequate system to convey the waste water. The Improper discharge waste water to surface water sources can adversely affect the human health and therefore, it is also important to understand how sanitation is closely related to human health. In the following sections, an attempt is made to correlate this issue with the help of the Interrelation ship diagram and the review proceeds to sanitation habit and health aspect with water supply and sanitation.

Figure 2: Interrelationships between urban services



Source: Cees Ketelaar, City Wide Sanitation, UEIM, IHS, 2010

2.3.2 Sanitation Habits

The availability of safe drinking water and the disposal of human waste are generally considered to be two prerequisites for a healthy life. However, the large portion of the population living in developing countries is still denying the access to hygiene and safe sanitation (Haldi, 2000). Sanitation was usually considered to mean sewerage which was not only expensive but not affordable to poor (Marais, 1973). Through awareness it has become popular among policy makers and now it is widely believed that safe water supply alone cannot do little to improve the health condition without similar progress in sanitation, because un hygiene sanitation reduces the potential benefits of a safe water supply by transmitting pathogens from infected to healthy person. The indiscriminate defecating in open and in surface water lives pathogen rich faecal matter thus contaminating the surface water which is again the source of water supply thus faecal-oral transmission continues (Hasan, 1995).

To understand the term sanitation habit, it is necessary to look at the term ‘sanitation behaviour’. If one segregates these two words, those can be defined as:

> “Sanitation is any system that encourages sanitary or healthy living conditions and it also includes a system to manage storm water, waste water, and solid waste and household refuse and further it also includes supply of

enough safe drinking water and for washing" (White Paper on Basic Household Sanitation, 2001).

Behaviour is the daily habit adapted regarding sanitation issues and this can have direct effect on drainage as well as sewerage system. Improper drainage can cause water stagnation and the stagnated water can cause dreaded diseases and these issues are outline below in the following sections.

The sanitation habit of a household such as cleaning, bathing, toileting, washing etc. has a direct impact on the water supply. The amount water requires by a household depends the sanitation behaviour of the household or the community.

2.3.3 Health Aspect of Water Supply and Sanitation

The interrelationship between water supply, sanitation and health are far more complicated than simply the influence of water supply on the provision of sanitation. For example, the availability of water for hand washing after defection has a very important role on the transmission of diarrhoeal diseases.

Water consumption figures are sometimes used in addition to the level of sanitation when comparing the health of different groups of people. Generally, a water consumption of 30-50 litres per person per day is often quoted as the minimum necessary for a healthy life. Diseases that are most dependent on personal hygiene for their control are: those due to highly infectious organisms that can be transmitted from faeces back to the mouth; and "water-washed" diseases, particularly of the skin and eye, that are controlled by washing (World Bank, 1986).

Water consumption is dependent not only on the standard of water supply service, but also by the available systems for disposal. Areas with very inadequate waste water disposal facilities may have very low rates of water consumption solely due to the difficulty of disposing of the waste water, and this in turn may affect the health of the people. For example, in the city of Natal in northeast Brazil the water consumption increased from roughly 25 litres per person per day to 50 litres per person per day when a sewerage system was installed, without any improvements being made to the water supplies in the area (World Bank, 1986).

The above facts highlights that it is most important to choose the sanitation technology which should match the level of water supply service if the development is going to be successful.

According to World Bank (1986) in many parts of the world, due to bad sanitation habit, environment and climatic conditions, certain water and sanitation related diseases are more prevalent and difficult to control and those who are working on this issue can control many of these by breaking the transmission routes. Most of these controls depend on behavioural changes within the households with women as the main agent for such transformation. These diseases are transmitted by various pathogens present in water or excreta.

Further it also posits that to fulfil minimum water requirement for a healthy life, one need to understand the concept of water demand. So, let us now examine the demand to understand the need of water and its various interpretations by different stakeholders.

2.3.4 Demand for Water

The term 'demand' has different interpretation to different people. The three most common interpretations are:

1. **Felt needs;** the 'felt needs' or aspirations of communities and to meet this demand, some projects are generally driven due to political or equity considerations;
2. **Consumption;** Most engineers tend to see demand as directly proportional to consumption. Thereupon, water supply scheme designs are generally based on volumes of water supplied to per household. The long term cost of these schemes, including maintenance and financial sustainability are often neglected (Webster 1999 as cited by Wedgewood and Sansom, 2003).
3. **Effective demand;** *"*can be defined as 'demand for goods and services which is supported with the resources to pay for it" (White 1997 and Pearce 1981 in Wedgewood and Sansom, 2003: 5).

In general, people merely *'want'* something and it may not be supported by a willingness to pay for that service. Therefore, there is a need to identify people's maximum willingness to pay for a service option. Sometimes, effective demand is referred to as economic demand by many people, and generally is the most meaningful definition of demand for these guidelines. It means, a water supply user must be able to support their expressed desire for improved water supply services by an ability to pay the required contribution towards this service (Wedgewood and Sansom, 2003).

The demand is closely related with daily requirement and according to UN-Habitat (2003) it is difficult to put a specific figure on an 'adequate' volume of water, but in most circumstances, at least 20 litres of water per person per day is essential, and 60 litres of water per person per day is required to allow sufficient water for domestic need such as washing, food preparation, cooking, cleaning, laundry and personal hygiene. However, more water will be needed if flush toilets are used.

The above facts highlighted the relationship between demand and daily requirement. Further daily requirement depends of type of sanitation habit and sanitation technology used which also depends on the financial capacity and willingness to pay. Therefore, it is very essential for a project planner to ascertain the financial sustainability of a project which is closely related with willingness to pay and same is being highlighted below.

2.3.5 Willingness to Pay

One of the most important issues for project designers and planners is how to ensure the financial sustainability of a project and this involves predicting what users will be able and willing to pay for water or invest in a system in the future. Un-served or underserved Consumers are often willing to pay a higher price for water than the tariffs charged. How much higher depends on how much water is being used and up to what level they are capable of affording.

Wedgwood and Sansom (2003) posit that people are willing to pay very high prices for basic minimum water requirements to ensure the survival of the household.

Willingness to pay (WTP) diminishes rapidly with nonessential levels of water use, therefore the relationship between WTP and water use can be shown by a downward sloping demand curve.

There are various definitions of willingness to pay (WTP); however, the most common one states that: ***"WTP** is the maximum amount that an individual states they are willing to pay for a good or service"* (DFID 1997 in Wedgwood and Sansom 2003).

The term willingness-to-pay can be confusing in a non-economic paradigm. Many users may not be 'happy' for paying a certain tariff, but they are *willing* to pay this amount rather than go without it, just as householders in the UK might not be happy paying their gas bills but know that they must pay them, or go without. (Webster 1999).

According to Wedgewood and Sansom (2003), there are three ways to estimate WTP:

1. To observe the prices that people pay in various market for goods (i.e. water vending, buying from neighbours, paying local taxes);
2. To observe individual expenditures of money, time, labour, etc. to obtain goods - or to avoid their loss. This method involves an assessment of coping strategies, observations, focus group discussions and even household surveys;
3. To ask people directly what they are willing to pay for goods or services in the future.

The first two approaches are based on observations of behaviour and are called ***revealed preference*** techniques. The third technique is based upon ***stated preferences*** and includes the contingent valuation methodology.

2.3.6 Affordability

Affordability can be defined as the ability of a consumer to pay a certain amount of price for a certain service. In another word, it the monthly income of a household that is spent on urban utilities such as water supply, power supply, garbage collections etc.

According to Flankhauser and Tepic (2007) in developing countries affordability cannot be directly derived from the household incomes. This is because house incomes are to a great extent sourced from many informal activities, and the household expenditure for food, religious and cultural obligations generally exceeds that spent on utilities. Moreover these expenditures need not be uniform throughout the year. The expenditure of a household here is a more accurate scale for affordability. Therefore the definition of affordability as expenditure on utility services as a share of total household expenditure may not be directly applicable for developing nations.

Thereupon, water poverty should takes into account the ratio between household expenditure on water and shortcomings in service quality. However, the present analysis is interested primarily in affordability related to installation of roof top rain water harvesting system against daily household expenditure on buying water from water vendors/neighbour sellers.

2.4 Conclusion

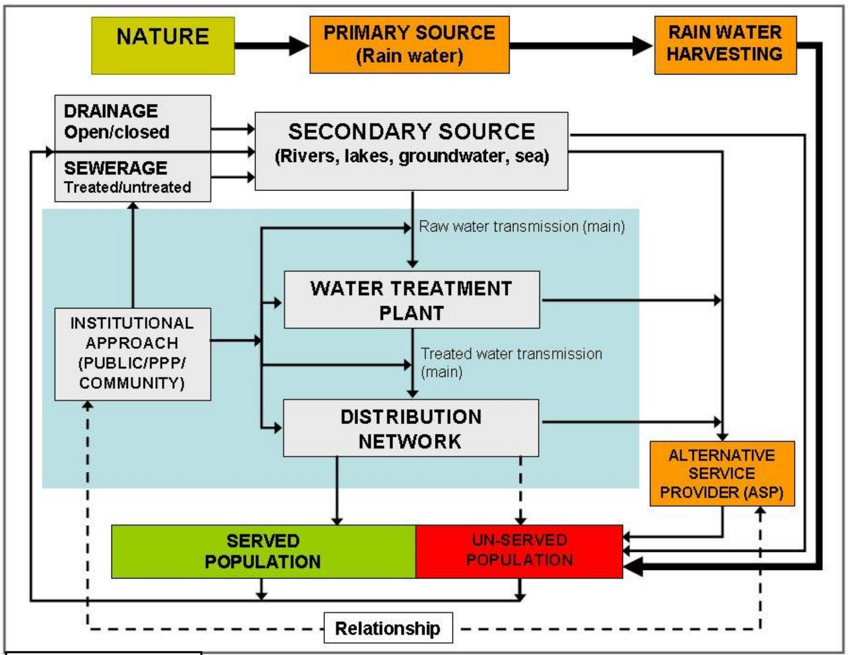
The literature review above illustrates various challenges faced by water utilities in providing potable piped water to its urban agglomerations. Various approaches including Private Sector Participation (PSP) have failed to achieve the targeted goal especially in low income areas because of commercial reasons. Thereupon, if we are committed in keeping pace with economic and population growth, we need to look for alternative renewable sources. This approach needs to look from a sustainable perspective and if required, we need to look back to our ancient practices.

Rain Water Harvesting (RWH) has been practiced by man kind since ancient times. Over a period of time, this ancient technique has been developed to more advanced forms, however the basic concept is still remains the same. To collect the water from rain, simple and appropriate technology can be employed to quench the thirst of millions. The most fundamental step in conserving our environment and resource demands for a change in people's behaviour and this includes each one of us. Rain water is the only renewable form of water and it is the primary source to all our rivers, lakes, wetlands.

Further it is also pertinent to consider whether or not such a system would be suitable in the research area. Hence the issue is related to the perception within the community, as well as affordability, demand, willingness to pay and sanitation habits–not just physical characteristics such as rainfall data, the type of catchment (roof) and the availability of skilled laborers and appropriate building materials.

2.5 Conceptual Framework

Figure 3: Conceptual framework



Source: Author

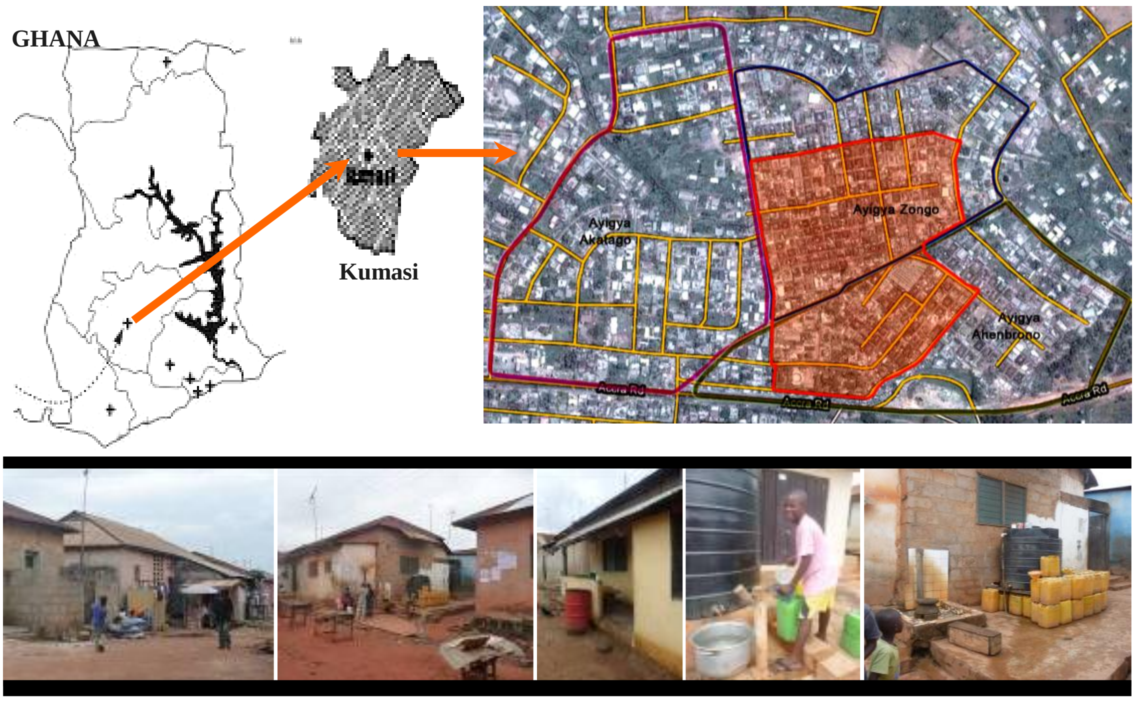
Chapter 3: Research Design and Methodology

The previous chapters have introduced the problem of water services and reviewed the body of knowledge on the approaches used in providing water services. It also highlighted inability of the formal sector in providing piped water supply and indispensable role of the informal sector, however, latter is characterized with high costs and dubious quality. Hence, it was found to be relevant to address the problem by looking at the potential of RWH as a supplementary and independent water source and this chapter explains the research design and mythology used in the field to collect the data and method of analysing it to yield correct inferences.

3.1 Description of Ayigya

Ayigya is a neighbourhood which lies in the eastern part of Kumasi, with a high population of migrants. It is about 5.7 km from the city centre and the major Accra-Kumasi road separates the neighbourhood from Kwameh Nkrumah University of Science and Technology (KNUST) and it bounded on the south by Kentenkorono and on the north by the Sisa stream. The neighbourhood has a population of 30,000 people; land area of 50 ha, 5,966 households and 1181 houses (Nyarko, Odai and Fosuhene, 2006). After brief introduction to Ayigya, the research design, approach and methodology employed in this research are explained below with reasons for adopting specific research strategies.

Figure 4: Map and pictures showing the research area, Ayigya



Source: Author, field work July 2010 and Google Earth Map, 2010 (modified by author)

3.2 Research Design

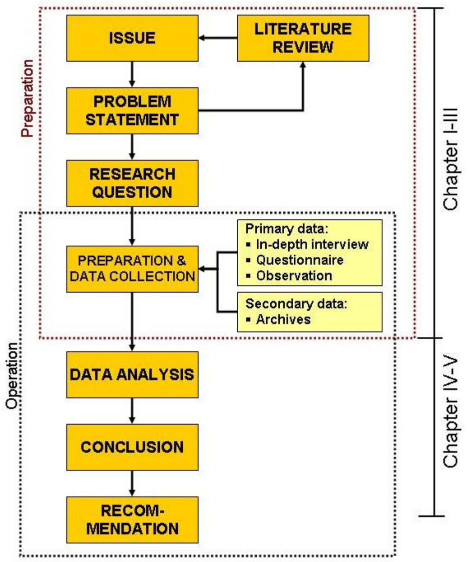
Research design is basically not related to particular method of collecting data. Any research design can adopt any type of research collection method and can use either qualitative or quantitative data. The main purpose of the research design is to minimize the chance of drawing incorrect inferences from the data (De Vaus, 2001).

Research design is basically a logical sequence that connects the empirical data to a study's initial research questions to its conclusions ultimately. The main purpose of the research design is to avoid the situation in which evidence does not address the initial research questions (Yin 2003). The research design also is useful to ensure the evidence obtained enables the researcher to answer the initial question as unambiguously as possible (De Vaus, 2001). According to Philliber, Schwab and Smsloss (1980), another way of thinking about the research design is a "blueprint" of research, dealing with at least four problems (as cited by Yin, 2003):

1. What questions to study;
2. What data are relevant;
3. What data to collect; and
4. How to analyse the results in a logical structure.

As stated above, the main purpose of this research is to investigate the role of both formal and informal sector and then focus on the potential of RWH to avoid overdependence on ASP by under and un-served urban poor. In this regard, the research design is started by developing credible and relevant questions for this study. This is followed by identifying the relevant data and the process of analysis. The detail of the research design used in this research is described in the following sections.

Figure 5: Research Design



Source: Author, 2010

3.3 Research Approaches

The literature on the research approaches categorizes all researches into three main approaches which include qualitative, quantitative, and mixed approaches. Mixed methods designs provide an important and useful contribution to extend methodologies in social science. It also holds potential for conducting research in organization by incorporating the value of both qualitative and quantitative data (Creswell and Creswell, 2003).

A Quantitative approach is one in which an investigator primarily uses post positivist claims for developing knowledge and employs strategies of enquiry such as experiments and survey, and collects data on predetermined instruments that yield statistical data. Whereas, in a mixed approach, data collection involves gathering of both numeric (quantitative) and text information (qualitative) so that the final database represents both quantitative and qualitative information. A qualitative approach is one in which the inquirer often makes knowledge claims based primarily on a constructivist perspective and include the multiple meanings of individual experiences, meanings of social and historical constructed, with an intent of developing a theory or a pattern or advocacy/participatory perspectives (Creswell 2003).

Considering the type of research, both qualitative and quantitative approaches are employed in this research. The justification for the use of both approaches to this study is that this research is interested in people's and organizations' perceptions on rain water harvesting and techno-financial feasibility of RWH which requires analysis of quantitative data. This kind of investigation hence requires a detailed description of the phenomena which involves both qualitative and quantitative approach.

3.4 Research Strategies

Research strategy is defined as how the research process is being designed and various authors tend to agree on the five main types of research strategies which include: experiment, survey, analysis of archival records, history and case Studies. According to Yin (2003), selection of the research strategy is determined by the following criteria:

1. The type and the form of research questions;
2. The extent of control an investigator or the researcher has over actual behavioural events;
3. The degree of focus on contemporary as opposed to historical events.

These criteria are summarized in the Table 2 below which illustrates the three major conditions applied to each potential research strategy.

Table 2: Relevant situations for different research strategies

Strategy	Form of Research question	Require control over behaviour events?	Focus on contemporary events?
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case studies	How, Why	No	Yes

Source: Yin, 2003

A brief description of each of the above research strategies is described below along with the reasons for adopting survey and archival analysis in this research is described below:

Experiment

Experiments are done when an investigator can manipulate behaviour directly, precisely and systematically (Yin 2003).

From above table, the experiment strategy has the forms of research questions of “how” and normally focuses on contemporary events. Although this situation is similar to the forms of this research which has also the "how" question with a focus on contemporary event, the experiment was not selected as a strategy for this research. This was due to the involvement of many aspects of social and political context noted in this research hence the use of experiment was found difficult to control and manipulate the behaviour events.

Survey

Survey is referred to as gathering of data or information from a sample or a specific population, usually by questionnaire, interviews, or telephone (Yin, 2003). In this research, to collect required data to answer the questions posed in this research, survey strategy is employed. In this respect, data are collected through in-depth interview with the GWCL officials, city utilities, professionals, sanitary shops, construction workers, meteorological officials and water vendors/neighbour sellers of Ayigya, Kumasi. In addition to above, a household survey of at least 68 households in the settlement was undertaken through closed ended structured questionnaires.

Archival analysis

This method is based on studying records or archives and is mostly dependent on secondary sources of data. This includes service records, organizational records, maps and charts, lists of names, survey data and personal records. In this research, secondary data are utilized i.e. documents and reports from urban water utilities, professionals, other water practitioners and meteorological department for collecting rain fall data. Although secondary sources of information were utilized, the archival analysis is not used as main research strategy for this study.

History

Histories are the appropriate strategy when there is virtually no access or control. They deal with "dead" past i.e. when no relevant persons are alive to report, even retrospectively, what occurred, and when an investigator must rely on primary documents, secondary documents, and cultural and physical artefacts as the main sources of evidence (Yin, 2003).

Although the history strategy method uses the form of research questions of "How" which is similar to the questions to be investigated in this research, the context of this research study is a contemporary event which seeks to investigate the role; therefore the history strategy is not feasible in this context and hence was not used.

Case study

A case study is an "empirical enquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003). This approach is used to study a social phenomenon through analysis of an individual case. All data relevant to the case are gathered and organized in terms of the case, and provide an opportunity for the intensive analysis of many specific details often overlooked by other research methods (Yin, 2003).

As described above, this research seeks to investigate the role of both formal and informal sector and look for potential of RWH as subordinate independent water source for under and un-served population. The above strategy is not suitable and thus the most appropriate strategy for this research were found to be survey and archival.

3.5 Research Type

Based on the objectives of this research, the type of research employed in this study is exploratory as it investigates the potential of rain water harvesting. Being exploratory in nature, this research could be a stepping stone for carrying out more detailed research in future to address the problems of water supply and potential of RWH in Kumasi, Ghana or other cities of West African countries. The Research method employed in this research in illustrated brief below:

Type of research	Exploratory
Research strategies	Survey, Archival
Data Analysis	Qualitative and Quantitative

3.6 Data Collection

The data are collected from all respondents except inhabitants of Ayigya using in-depth interviews and partially semi-structured questionnaire. In case of inhabitants of Ayigya, data are collected through structured questionnaires, observation and selected in-depth interviews. Digital recording and digital pictures are used to store data collected through interviews and observations. The following tables show list of respondents:

Table 3: List of respondents

No.	List of Respondents	Definition/Description	Method for data collection
Community			
1	Inhabitants (68 households) through random sampling	Those who are residing in the neighbourhood.	Structured Questionnaire
(Local) Government representative (formal sector)			
2	GWCL	Project Manager Ashanti Region	In-depth interview using semi-structured questionnaire
3	Local Meteorological Department officials	Those who are involved in collection of local rainfall data	
4	KMA (Kumasi Metropolitan Assembly)	Estate Officer	
Private Sector and others			
4	Professional/KNUST	Dean Dept of Architecture and Mr. KB. Nyarko from Dept of Civil Engineering	In-depth interview using semi-structured questionnaire
5	Three (3) numbers of water vendors/neighbor sellers (informal sector)	The persons who own and operate as alternative service providers i.e. neighbourhood seller, water vendors etc.	
6	Three (3) numbers of Sanitary and hardware shops	Those who sell plumbing materials, building materials and prefabricated materials	
7	Three (3) numbers of construction workers	Those who are involved with building construction and building materials.	

3.7 Data Analysis

The types of assessment method employed for data analysis are both qualitative and quantitative approach. The first step of qualitative data analysis is to organize the collected data into a logical order. The initial steps need formalization of data, indexing, labelling (i.e. decoding); categorizing, typology (i.e. interpretation of data for qualitative approach) and the same method are employed in the analysis. The quantitative data are processed using Excel software and results are displayed in graphs and tables by using simple statistics method (percentage) analysis.

3.8 Variables and Indicators

Variables and indicators of this research are as below:

Table 4: Summary of research questions in relation with variables and indicators

NO.	RESEARCH QUESTIONS AND SUB QUESTIONS	VARIABLES	INDICATORS
1	How does the government piped water supply organized in Ayigya, Kumasi?	Institutional arrangement	• Water Treatment plants • Distribution networks • Rehabilitation measures • Connection procedure
	a. Who are the stakeholders?	Supply chain	• Water company • Small Water Enterprises (SWEs) • Customers
	b. In how far does Ayigya population depend on this piped supply?	Household coping strategy	• Number of connection • % demand met from piped source • Storage facilities
	c. What is the actual cost & quality of water?	Monthly bill	• Water tariff • Water quality/perception
2	How is the supply system organized by ASPs in Ayigya, Kumasi?	Storage source	• Type of infrastructure and storage facilities employed by the water vendors
	a. Who are the stakeholders?	Supply	• Number of formal water connection • Scarcity period • Relationship between water utilities and vendors • Individual boreholes as supply source
	b. What is the size of the population which depends on ASPs?	Demand	• Willingness to pay • Household size • Sanitation habit • Income and expenditure • Health of the family
	c. What is the actual cost & quality of water?	Household expenditure on water	• No. households without water connections • Variation in expenditure on water • Number of users
3	What is the technical and financial feasibility of adopting household Rain Water Harvesting (RWH) as a supplementary source of water for the affected population? a. Which appropriate technology should be adopted in order for RWH to be sustainable?	Type of ownership	• Rental • Self-owned • Amount spend on accommodation
		Physical condition of the house/quality of house	• Wall • Floor • Roofing material, • Sanitation facilities
		Rainfall pattern	• Monthly precipitation/annual rainfall
		Critical demand	• Size of the household • Sanitation behaviour • Daily consumption of water
		Perception of the community	• Beliefs in regard to water • Level of acceptance to change, • Social taboo
		Willingness to pay	• Income • Paying capacity • Perceived benefit
		Availability of materials	• Availability of gutter, sprouts, PVC pipes, etc. in local market.
		Skilled labour	• Availability of skilled local Labourers
		Knowledge	• Technical knowledge on RWH • Skill to manage community • Vocational training centre/ institute
		Availability of funds	• Income/ employment status • Paying capacity, expenditure • Loan from financial institutions

Having described in detail the research method adopted in this research, the following chapter presents the results of the research.

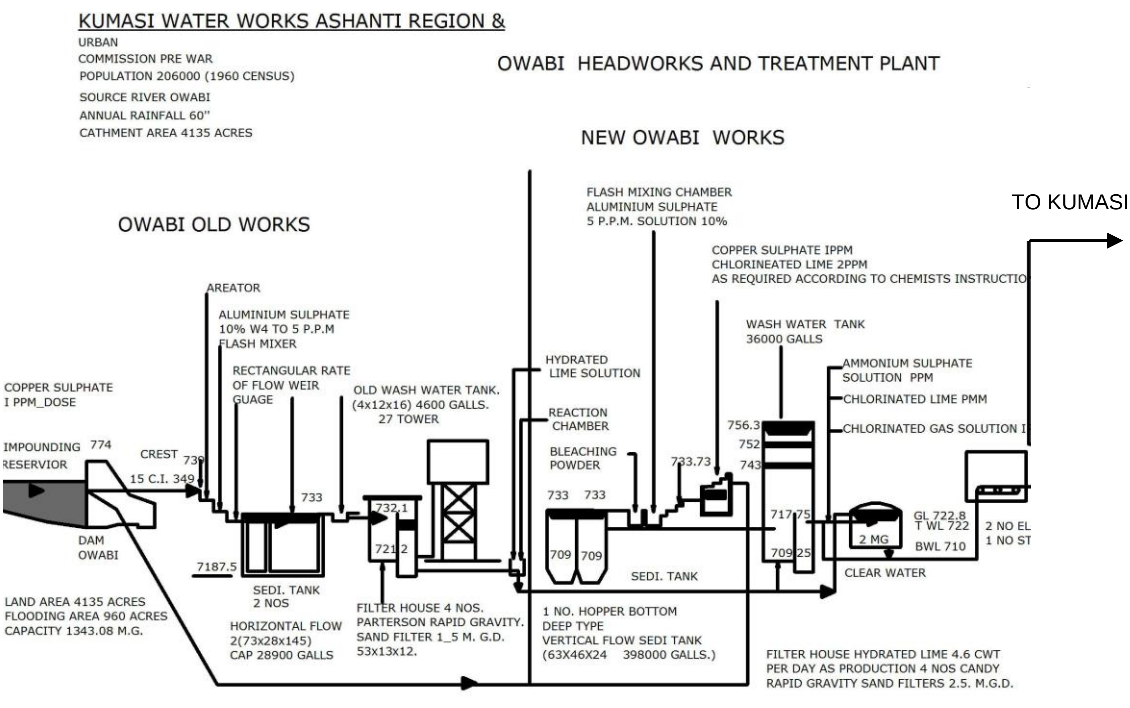
Chapter 4: Research Findings and Data Analysis

This chapter presents the research findings based on the research conducted in Ayigya in July, 2010 in order to answer the three main research questions along with their sub questions. The first two findings are focused on the existing water supply situation in Ayigya, which includes formal (government) piped water supply system from Ghana Water Company Limited (GWCL) and informal (ASPs) water supply system from water vendors/neighbour sellers in order to portray the actual situation there. The third and the most important finding for this research is focused on the techno-financial feasibility for adopting the rooftop RWH system at household level using locally available materials and technologies against the backdrop of the first two findings.

4.1 Organization of GWCL Piped Water Supply in Ayigya

According to an in-depth interview with Mr. Timothy O. Nettey, Project Manager, GWCL, Ashanti region on 14th July, 2010, at his office chamber in Kumasi, the main water supply to Kumasi comes from the Owabi and Barikese reservoirs. Owabi reservoir is located approximately 10 km to the North West of Kumasi and was built in 1932 and in 1952 the capacity of the reservoir was increased to 13,600m^3/day to meet the growing demand. At present, Owabi plant has an install capacity of 11,340m^3/day (3 million gallons/day). Figure 6 below, shows the detailed components of Owabi treatment plant along with the main distribution pipes to Kumasi.

Figure 6: Components of Owabi Water Treatment Plant, Kumasi, Ghana



Source: GWCL, 2010, modified by author

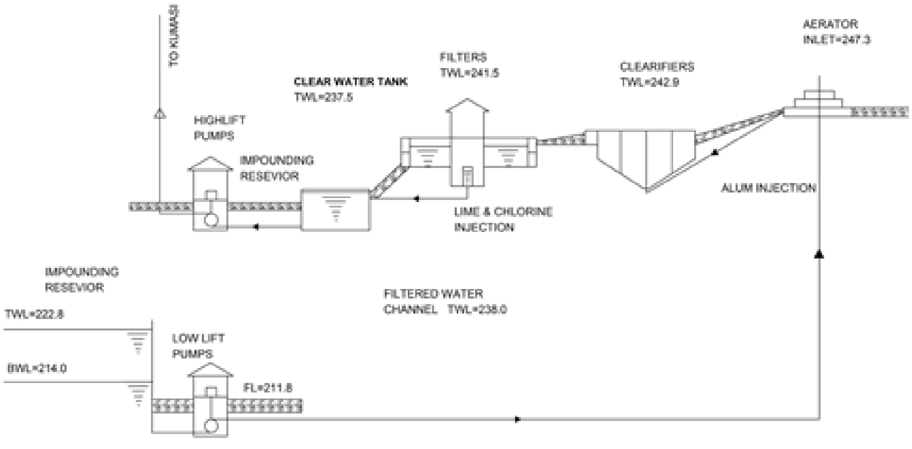
Owabi water treatment plant comprises of Owabi old works and Owabi new works and treated water from both plants, is pumped to Suame distribution service reservoir through a 14" diameter cast iron pipe from where it is further distributed to different parts of Kumasi. Owabi WTP had an actual production of 11,108m^3 /day in 2009 against the installed capacity of 13,636m^3/day and this may be due to the aging of the plant as the plant was commissioned nearly eight decades ago.

The second water treatment plant, i.e. at Barikese reservoir, is located approximately 19 Km North West of Kumasi and was constructed between 1967 and 1971. The plant comprises of a dam on the Offin River, a pumping station for raw water, treatment components, treated water and 900 mm (36 inches) transmission pipeline to Suame distribution centre. The WTP in 2009 had production of 72,727m^3/day against the installed capacity of 218,181m^3/day. The present installed capacity of the plant is around 68,040m^3/day (18 million gallons/day) and by the end of 2010 the targeted production is 90,720m^3/day (24 million gallons/day). To achieve this target, the GWCL undertook a massive rehabilitation and capacity expansion work in 2007 and the contract work was awarded to Ballast Nedam (GH) limited. The total contract amount for the aforesaid work was 37 million Euros and the contract period was from 2007 to 2009. As a result of said work, there has been a slight improvement in water supply in Kumasi due to increased production capacity. The major works for capacity expansion at the Barikese water treatment plant include:

- Construction of additional aerators
- Replacement/installation of all four low lift pumping units
- Construction of a third clariflocculator
- Construction of six additional new filters
- Replacement/installation of all four high lift pumping units
- Construction of a booster station in Achaise

The water treatment process in Barikese begins with extraction of raw water from the dam at the intake tower and it flows by gravity to the low lift pump house, from where the raw water is lifted through a height of 35 meters to an aerator inlet. At the aerator, the raw water is exposed to the atmosphere to avoid foul odour and then the water is delivered to clarifiers through gravity. The clarified water from the clarifiers then flows to the sand filter where residuals are removed for clear water to emerge. In the next step, chlorine and lime are added to disinfect and correct the pH value and water is channelled to a clear water storage tank and finally to the high lift pump house from where the water is pumped to Suane distribution centre and finally to Kumasi city. Figure 7 illustrates various components of the Barikese water treatment plant along with the distribution main to Kumasi from high lift pumps.

Figure 7: Barikese Water Treatment Plant



SCHEMATIC DIAGRAM FOR WATER TRATMENT WORKS AT BARIKESE

Source: GWCL, Kumasi, 2010 (modified by author)

At present, Owabi and Barikese together produce 79,380m^3/day[1]. By the end of 2010, Barikese is expected to produce 90,720m^3/day and expected total production from both WTP is 102,060m^3/day and expected demand and supply gap will be 21,226m^3/day[2]. Table 5 clearly shows that the projected water demand by 2015 is 123,286m^3/day and demand and supply gap will be 54143m^3/day.

This gap will have an impact on the large chunk of the population in the region and seek to look for alternative water sources. As both the plants are ageing, there may be technical difficulties in further expansion in their production capacities. The distribution networks need to be upgraded to suite the demand. One of the main reasons of intermittent water supply in Kumasi may be due to extension of distribution network beyond their hydraulic capacity to meet the growing demand due to population growth. This challenge to extend the water service seems to be daunting due to insufficient finance for new distribution network, rehabilitation and maintenance. This situation is similar to what literature review have elucidated that public utilities are unable to keep pace with the growing population further they are faced with insufficient funding for maintenance, leading to a deterioration of assets.

Table 5: Projected water demand in Kumasi

YEAR	ESTIMATED POPULATION	PROJECTED WATER DEMAND (m^3/DAY)
2005	1,102,149	97,424
2007	1,166,613	105,180
2008	1,200,000	109,091
2011	1,307,271	123,286
2015	1,465,190	144,863
2025	1,950,390	212,479

Source: GWCL, Kumasi, 2010

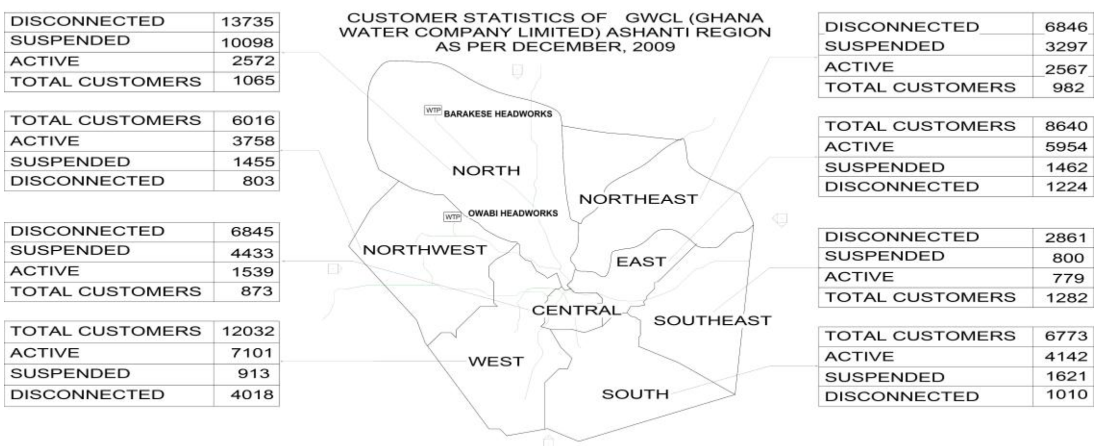
[1] (11,340 m$^{3/}$day from Owabi WTP and 68,040 m^3/day from Barikese WTP

[2] Supply gap is calculated from projected supply minus projected demand

For administrative convenience, Kumasi has eight revenue districts namely North, North-East, East, South-East, South, West, North-West and Central and has a total of 63,748 customers with 39,583 active customers, 12,908 suspended customers and 11,257 disconnected customers. Figure 8 illustrates district-wise the total number of customers along with the total number of active, suspended and disconnected customers. North district has the highest number of customers – a total of 13,735, out of which 1,065 are disconnected, 2,572 are suspended and 10,098 are active. This figure shows that North district has the highest number of active customers in Kumasi. On the other hand, the South-East district has the lowest number of customers with a total of 2,861, out of which 1,282 are disconnected, 779 are suspended and only 800 customers are active. This shows that in the South-East district, only 27 per cent of customers have access to piped water. This may mean the majority of them have access to water from alternative means.

The research area i.e. Ayigya, lies in the South-East district and has very few active customers from GWCL and the majority of them are water vendors according to a field survey and observations by the researcher.

Figure 8: District wise customer statistics, Kumasi



Source: GWCL, Kumasi, 2010 (modified by author)

Access to the Water Service by Residents of Ayigya

After being produced at Owabi and Barikese, water is pumped to Kumasi and distributed among consumers in various districts through the distribution network which comprises of a combination of single pipe, looped and branched. This type of piping network is similar to a typical water distribution network, explained in the literature review. The GWCL main distribution pipe in Ayigya area is 100mm diameter GI pipe and from it, the individual connections are provided in 75mm diameter PVC pipes.

According to GWCL Kumasi office, the South-East district where Ayigya lies has a total of 800 active customers and the researcher found only 23 active water connections in the narrower research area, the majority of which are water vendors. This indicates that the majority of the population depends on alternative sources.

Figure 9: Individual water connection pipe

Source: Author, field work, July 2010

Figure 10: Main GWCL distribution

Source: Author, field work, July 2010

As mentioned above, there are very few individual water connections in Ayigya and those who have the connections are mostly water vendors/neighbour sellers and they generally store the water in PVC poly-tanks or in masonry tanks. The water supply from GWCL does not always flow all the time during the day and sometimes, it flows at night from 10pm to 5am in the morning only. Thereupon, all the people with the water connections have water storage tanks ranging from 1,000 to 10,000 liters capacity as a coping strategy to meet the eventualities. In addition to the intermittent daily supply, sometimes water flows for only a few days in a week and stored water is used during those periods.

The distribution network in Ayigya area is also quite bad as the distribution pipes are not properly laid into the ground and the researcher observed that some of the main distribution pipes are even exposed to the elements and run very close to open drainage and there is a high possibility to ingress contamination through broken distribution pipes from open drainage. There are numerous signs of leakages in the distribution network.

The above sections have explained the process of piping water to Ayigya from Owabi and Barikese water treatment plants. In the following sections, an attempt is made to explain the process of accessing the piped water supply from GWCL by a consumer in Ayigya, Kumasi.

Connection Procedure

For a new connection, an applicant must apply to New Service Connection Unit (NSCU) of GWCL district and the following steps to be followed:

1. Application to be submitted in written or verbal to GWCL District office;
2. Applicant purchases GWCL New Service Connection form and duly filled and returns the completed form to GWCL District Office together with site plan of the plot/ premises where the new connection is required. (The new application form costs GH¢ 3);
3. On receipt of the duly filled application form, GWCL District Office fixes a date for joint physical site inspection between the applicant and GWCL;

4. A joint physical inspection of the site is carried out on the fixed date not exceeding three working days after submission of the completed form;
5. Based on the joint site inspection, GWCL prepares an estimate of the materials required with total estimated cost for the proposed new connection;
6. GWCL and applicant agree on cost sharing (if any) and mostly applicable to real estate developers;
7. A final bill is prepared based the above two steps by GWCL district manager for final approval by GWCL regional office;
8. Applicant makes full payment of approved final bill (the estimated cost) including any other costs agreed to be borne by the applicant in step 6 (within 14 days thereafter);
9. New connection service is affected by GWCL, within 14 days of full payment by applicant;
10. GWCL District Manager issues a NSC completion report to GWCL Regional Office Head;
11. GWCL issues a NSC completion Report to applicant for confirmation of satisfactory completion by GWCL.

This process seems very lengthy and time consuming aside from high connection charges. The connection fees are quite high as consumers have to purchase all materials required in the piped water connection.

Billing

Once the water connection is installed to a customer, the commercial manager of GWCL's Kumasi office is responsible for revenue collection from all water districts in Kumasi. Each district is divided into zones, and each zone has someone in charge for meter reading. The reader brings his findings to the office, where the billing clerks prepare the bills, based on the tariffs and the bill is served to customers on the 15th of each month, who is given approximately two weeks to pay. The consumer than goes to the GWCL district office and pays the bill at the finance department of that office. If the customer fails to clear the outstanding bill within a period of one month, a notice is served to the customer and if he or she still fails to pay, the connection will be disconnected and they must pay a reconnection fee.

The sections above explain the procedure of getting a new water connection from GWCL along with its billing system. The following section presents the researcher's observations with regard to problems faced by residents of Ayigya.

Problems Residents Face with the Water Service

As mentioned above, not all households in Ayigya have their own private tap; consequently the majority of the households buy water from water vendors. Further, a large proportion of Ayigya's households occupy rented accommodation, which are mostly single-story compound houses. The average household size in Ayigya is 5-6 persons and it is fairly common for a household to rent 2 rooms. The average household water consumption is around 100-120 liters a day and they spend nearly GH¢ 1 per day on buying water from water vendors. To make matters worse, the quality of service provided by the water vendors is poor compared to the price they charge their customers.

The general problems faced by residents concerning the water service in Ayigya are:

1. Inadequate water supply connections in view of the size of the population;
2. 91.2 per cent (66 out of 68 respondents) of the households buy water from water vendors;
3. On an average, a household spends nearly GH¢ 1 to GH¢ 1.3 on buying water from water vendors[3];
4. Severe increase in GWCL water tariffs since June 2010 (34 per cent increase); this will have an impact on the price of the water from water vendors and a minimum expected price hike of GH¢ 0.134 per jerry can.

The above sections explain the detail of the water supply procedure organized by GWCL and some of the typical issues experienced by the respondents in the research area. In the following sections, an attempt is made to answer the sub questions of research question one.

4.1.1 The Stakeholders

Ghana Water Company Limited (GWCL, Ashanti Region) is responsible for the supply of potable piped water to Kumasi and its environs. GWCL entered in to a management contract with Aqua Vitens Rand Ltd. in July, 2005 and under this management contract, Vitens is managing the water supply system in Ghana including the Ashanti region on behalf of the GWCL since the inception of the PPP contract. In this contract, the grantor is Ghana Water Company Limited, which is wholly owned by the Republic of Ghana and on the other hand the selected bidder i.e. Vitens Rand Water Service B.V. is a consortium between Vitens International B.V. of the Netherlands and Rand Water Services of South Africa. Vitens Rand was selected for a period of five years to operate urban water supply with responsibility for directing and managing GWCL staff (except those in GWCL head office that constitute the asset holding company). The operator works under a management contract and is also responsible for billing and collection of tariffs. In June, 2010, the water tariffs were restructured and there has been an increase of 34 per cent in the tariff. Similarly there is also a substantial increase in the water connection charges.

Table 6 illustrates GWCL's district wise statistics of active, suspended, disconnected customers along with the total number of customers in Kumasi and they are the main stakeholders from demand side. As mentioned above, the research area in Ayigya has only 23 active water connections and the majority of them are water vendors.

[3] present price of water is GH¢ 0.1 per jerry can (one jerry can equals to 20 litres)

Table 6: Customer statistics

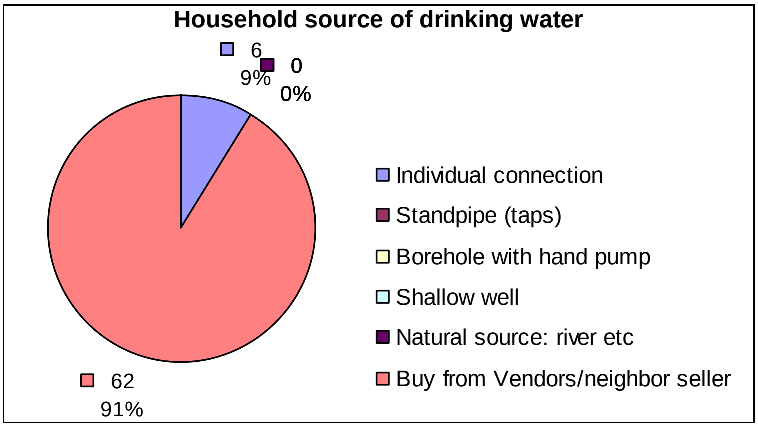
CUSTOMER STATISTICS OF GWCL (GHANA WATER COMPANY LIMITED) IN ASHANTI REGION PER DECEMBER 2009					
NO	**DISTRICT**	**ACTIVE**	**SUSPENDED**	**DISCONNECTED**	**TOTAL**
1	North	10,098	2,572	1,065	13,735
2	Northeast	3,297	2,567	982	6,846
3	East	5,954	1,462	1,224	8,640
4	Southeast	800	779	1,282	2,861
5	South	4,142	1,621	1,010	6,773
6	West	4,433	1,539	873	6,845
7	Northwest	7,101	913	4,018	12,032
8	Central	3,758	1,455	803	6,016
	Total Customers	**39,583**	**12,908**	**11,257**	**63,748**

Source: GWCL, Kumasi, 2010

4.1.2 Population that Depends on GWCL Piped Water Supply

Figure 11 below illustrates that out of 68 respondents; only 6 of them have individual piped water connections from GWCL. This shows that only 8.8 per cent of the respondents have access to individual water connections and the majority of them have no individual water connections and buy water from those who have the connections (water vendors/neighbour sellers).

Figure 11: Household source of drinking water



Source: Analysed data, field work, July 2010

The researcher also interacted with the chief of Ayigya Zango, Md. Bashihr Saeed, during the field work in Ayigya and with regard to individual water connections, he reveals that there are only 23 active water connections in the research area in Ayigya and most of them are water vendors except the connections located at plot-76, block-U (The Mosque), Plot- 7, block-V (Usman) and plot-69, block-U.

4.1.3 Cost and Quality of GWCL Piped Water

There has been a 34 per cent hike in the water tariff, which took effect from June, 2010 and it has an impact on the customers and many of them are complaining about the enormous hike in the water tariff. According to the researcher's in-depth interview with Mr K B Nyarko of KNUST, there has been even a debate in the parliament regarding the water tariff. Table 7 below shows percentage of price hiked and a comparison between the old water tariffs and newly approved water tariffs effective from June, 2010. This price hike may have a serious implication for both served and un-served customers. The implication may be more on the un-served customers as the un-served customers depend largely on water vendors/neighbour sellers for their daily water demand and pay almost 7 times more than that of the urban utility providers. On the other hand water vendors/neighbour sellers to a large extent depend on GWCL water supply for their water vending business.

Thus, this increase in GWCL water tariffs may have an impact, primarily on the poor, who buy water from water vendors/neighbour sellers. The poor are deprived from both the economics of scale and government subsidies, and so they have to pay an excessive price for water compared to their rich counterparts. These facts support the idea first discovered in the literature review–the poor pay more for water in most of the developing countries.

Table 7: Comparison between old and newly approved water tariffs

NO	CATEGORY OF SERVICE	MONTHLY CONSUMP-TION (1000 Litres)	APPROVED RATES in GH¢/1000Liters, Effective 01-11- 2007 to 02-2010	APPROVED RATES (II) in GH¢/1000Liters, Effective 1-6-2010	Percentage of Hike in Water Tariff
(a)	Metered Domestic	0 - 20	0.66	0.80	30.3%
		21 and above	0.91	1.20	31.8%
(b)	Commercial/Industrial	Flat Rate	1.10	1.80	63.6%
(c)	Public Institutions/ Govt. Departments	Flat Rate	1.10	1.54	40%
(d)	Un-metered Premises– (Flat rate per house per month)		3.89	5.20	33.6%
(e)	Premises without connection (Public standpipes) per 1000 litres		0.66	0.80	21.2%
(f)	Special Commercial		2.04	4.79	134%
(g)	Reconnection Fee:				
	(i) Domestic	GH¢	2.88	3.74	29.8%
	(ii)Commercial/Industrial	GH¢	9.22	11.99	30%

NOTE: Special commercial refers to bulk customers who use GWCL treated water as the main raw material for bottling water for sale

Source: GWCL, Kumasi, 2010 (Comparison prepared by author)

In the past, not every household was equipped with a water meter to record the level of water consumption but now GWCL is providing water meters to all the new connections and the cost of a new meter is GH¢ 45. Those without a water meter are encouraged to install water meters and those without it still pay a flat-rate monthly charge. Regarding the service and quality of water, the researcher's in-depth interview with respondents in Ayigya with water connection reveals the following facts:

Service

Complaints of irregular supply with frequent water shortages are quite common. Residents who have water connections often complain that water does not flow at all during the day. Typically, it flows at odd hours. In addition to the intermittent daily supply, water supply is not regular throughout the week. However, there has been a slight improvement with regard to intermittent daily supply since March 2010.

Low Water Pressure

The researcher observed that the low pressure is caused by leakages in the distribution system and incorrect pipes sizes. When the water supply distribution network was planned in Kumasi and Ayigya area, they did not consider the future urban expansion, and the distribution network has very small diameters supply pipes. Furthermore, residents generally attributed the low pressure to insufficient pumping capacity. This refers to the shortage of boosters to pump the water through the network of narrow pipes. Low pressure was also considered to be a more severe problem during the dry season.

Quality of Water

In-depth interviews with some residents with water connections in Ayigya reveal that there is occasional presence of small particles in the piped water. This is caused by the use of old rusty pipes in the distribution network, and the leaks in the pipes which allow dirt to penetrate into supply pipelines. Especially after an interruption in supply, the water appears brownish in colour and contains dirt and specks of rust. Also low or negative pressures in the mains could lead to ingress of polluted groundwater.

However, of late, there has been improvement in flow and quality of water according to an in-depth interview with Mr. Ango Abulaisi, (Water Vendor) plot no-49, block-U and further the household survey analysis of 68 respondents reveals that 60 per cent of the respondents were of the opinion that the quality of piped water from GWCL is good and they do not agree with presence of mud and dirt in piped water whereas 38 per cent of respondents feel the vice versa.

In the above sections, the researcher explains how the water supply system is organized by GWCL in the research area. It also highlighted various measures undertaken by GWCL to enhance the capacity of treated water production and its distribution system. However this challenge seems daunting, considering the existing piped water supply systems and high population growth in Kumasi. By 2015, the projected demand and supply gap is 54143m^3/day which is quite enormous to be met from the present water treatment plants and its distribution system. The Owabi plant is aging fast and there are limitations to further increase in its capacity. Further, Barikese plant too has its own technical limitations and the new rehabilitation work of the plant in 2009 could increase capacity by only 22,680m^3/day at a cost of 37 million Euros.

On the management side, the PPP between Aqua Vitens Rand Ltd. and GWCL has improved in revenue collection and disconnection of non-paying customers but it has a reluctance to provide connections to areas of low return on capital because of economic reasons. This situation is in line with the literature review which reveals that privatization entails a more commercial approach to the provision of services, which can lead to the withdrawal of subsidies, an increase in price, the more frequent disconnection of non-paying customers, and reluctance to connect new customers unless they will be profitable. As a result, the researcher is concerned about its effect on the poor, irrespective of its possible benefits in other areas. Consequently, solutions to this problem should be looked for considering alternative sources of water by encompassing technical, financial and behavioural means in order to achieve sustainability in the long run by the affected population. In the next section below, the researcher makes an attempt to paint how the water supply system is organized by water vendors/neighbour sellers in Ayigya in an informal way to address the need of the un-served population.

4.2 Organization of Water Supply by ASPs in Ayigya

The water vendors/neighbour sellers generally have a water connection from GWCL and employ sufficiently large storage tanks to store water. Aside from GWCL connections, most of them have individual boreholes within their premises and use them as a supplementary source of water for their regular water business. The boreholes are generally 80 to 120 feet in depth and most of them employ vertical submersible pumps to extract water from the groundwater and the extracted water is stored in storage tanks. Those households without any individual pipe water connections from GWCL buy water at GH¢ 0.10 per 20 liters (jerry can), which is over six times higher than the price charged by the urban utility provider. This figure is highly likely to increase further once the 34 per cent hike in GWCL water tariffs is passed on by water vendors/neighbour sellers.

Figure 12: A typical water vendor in Ayigya

Source: Author, field work, July 2010

Figure 13: A house of a water vendor with a borehole

Source: Author, field work, July 2010

The in-depth interview conducted by the researcher with Mr. Ango Abulaisi, (Water Vendor) plot no-49, block-U reveals that he has a water connection from GWCL and an individual borehole for his business. He has two storage tanks of 450 and 1100 gallons capacity each and sells around 200 to 250 jerry cans per day. The borehole located just outside his premises has 150mm diameter galvanized iron pipes ingress to a depth of 36 M below into the ground and inside it, he has installed a 3" diameter, 2 horse-power submersible vertical pump to extract the ground-water from a depth of 120 feet. The monthly electricity bill for using the pump along with few other household appliances is around GH¢ 80 which he pays regularly to keep his business running.

The researcher's interview with another neighbour seller named Abdul Karim (plot-5A, block-X), reiterates that he too has a regular water connection from GWCL and a borehole installed with a vertical submersible pump within his premises for his water vending business. He has constructed a huge masonry water storage tank in the open courtyard of his compound house and sells around 300 gallons of water every day. He pays a regular bill of GH¢ 80 to GWCL for his monthly water consumption besides the electricity bill of GH¢ 60 for using the submersible pump and his other household appliances including lighting. This respondent further highlighted that water does not flow generally during the day. Typically, it flows at night from 10pm to 5am in the morning and water sometimes flows only for a few days in a week, therefore, it was essential for him to construct a sufficiently large water storage tank for his business. This illustrates the coping strategies adopted by water vendors to supply un-interrupted water to their customers for commercial reasons.

4.2.1 The Stakeholders of ASPs

Regarding the total number of water vendors/neighbour sellers, the in-depth interview with the Chief of Ayigya Zango reveals that there are in total 19 water vendors in the research area and their details are illustrated in table below. The majority of the households in the research area depend on them for their daily household water demand.

Table 8: List of water vendors/neighbour seller

SERIAL NUMBER	PLOT NUMBER	BLOCK CODE
1	71	A
2	1	V
3	1	H
4	2	H
5	9	G
6	2	V
7	25	V
8	7	S
9	26	V
10	2	H
11	10	T
12	8	Q
13	44	X
14	20	X
15	10	T
16	4A	Z
17	60	Z
18	37	R
19	5A	X

Source: Author, field work, July 2010

4.2.2 The population that depends on ASPs

Figure 14: Example of neighbour seller

Source: Author, field work, July 2010

The data analysis of 68 respondents shown in figure 14 illustrates that 91 per cent of respondents have access to potable water through water vendors/ neighbour seller and only 9 per cent of the respondents have access to potable water though individual connections. This percentage is almost in line with the outlined figure in the problem statement in chapter one. Further, in Ayigya, there are no natural water sources such as ponds, streams or rivers which are fit for human consumption there upon the un-served population depends only on ASPs. This statement can be further supported by Figure10 below, which illustrates that 85 per cent of the respondents do not agree with fetching water from rivers/ponds during the scarcity period, whereas 12 per cent of them do not agree at all. These facts are in collaboration with the literature review which outlines that in developing countries, in the absence of utility services, small scale independent water providers or Alternative Service Providers step in to fill the gaps left by the water utilities and according to the World Bank (2001), these providers account for up to 70 per cent of service provision in some developing countries.

4.2.3 Cost and Quality of Water from Water Vendors/Neighbour Seller

The in-depth interview with three water vendors and a couple of respondents reveals that the cost of one jerry can (20 litres) of water is GH¢ 0.10. In Ayigya, on average, a household spends GH¢ 0.50 to GH¢ 1.00 per day on buying water and their monthly household expenditure on water is around GH¢ 20-25. This can be further collaborated with the household survey of 68 respondents which reveals that 52 per cent of the respondents in Ayigya spend less than GH¢ 1 per day on buying water from water vendors and 42 per cent of them spend GH¢ 1- 2.5 whereas 6 per cent of the respondents spend GH¢ 2.5-3. However, the in-depth interview with the aforesaid three water vendors reveals the probability of increasing the price of water once the 34 per cent hiked water bills from GWCL are served to them. At the time of conducting this research, the new, 34 per cent hiked water bills from GWCL were yet to be served to the customers and water vendors were not in the position to tell their projected price hike in water. However they indicated a corresponding increase in their price of water in line with the GWCL rate and thus the projected price of one jerry can of water is illustrated below:

Cost of one jerry can of water from water vendor	= GH¢ 0.1 (before tariff hike)
Projected price per jerry can = (34/100X0.1)+1	= GH¢ 0.134 (after tariff hike)

Note: Conversion of GH¢ 1.00 equals to € 0.57

Regarding the quality of water, majority of the respondents i.e. 72 per cent feel that the quality of water they buy from water vendors are good. 24 per cent of the respondent agrees that there is always mud and dirt in the water they buy from water vendors/ neighbour sellers whereas 3 per cent of the respondent do not agree at all in the aforesaid statement. These figures also illustrate that majority i.e. 75 per cent of the respondents agree that the quality of water they buy from water vendors are good. The quality of water provided by water vendors also depend on the following factors:

1. Type of water storage facilities and hygiene employed by the water vendor;
2. Quality of piped water supply from GWCL;
3. Quality of water from their respective boreholes.

Type of Water Storage Facilities and Hygiene

Most of the water vendors use PVC Poly tanks to store both piped water from GWCL and extracted water from their individual boreholes. Few vendors also used sandcretes water storage tanks and jerry cans to store water for sale. The storage tanks are generally located either outside their compound house or within the open to sky courtyard of their compound houses and they are raised around 1'6" to 2'00" from the ground level and surrounding floors are paved with plain cement concrete (PCC) flooring. This makes the area clean and the storage tanks are always covered with suitable lids. The 2'00" raised podium also helps in gravity discharge of water from the storage tank to customer's buckets/ jerry cans/ pans.

Figure 15: Storage facilities used by a water vendor

Source: Author, field work, July 2010

Quality of Piped Water Supply from GWCL

As most of the vendors primarily depend on piped water supply from GWCL for their water vending business, thereupon the quality of water they sell depends on the quality of piped water they get from GWCL. The previous section which deals with quality of GWCL supplied water, illustrated that 60 per cent were of the opinion that the piped water from GWCL does not contain mud and dirt and this perception has an impact on the quality of water provided by water vendors.

Figure 16: Connection GWCL

Source: Author, field work, July 2010

Quality of Water Extracted from Boreholes

Another primary source, on which water vendors depend, are the in-house individual boreholes. These bore holes are mostly 80-100 feet in depth and installed with electric submersible pumps to extract water. Some of the boreholes are well constructed and provided with adequate measures to protect from unwanted infiltrations.

Figure 17: Example of borehole well

This picture shows a well-constructed borehole with sufficient measures to protect from unwanted infiltrations. Inside it there is a 150mm diameter galvanized iron casing which is inserted 36 M deep in to the ground. Inside the 150mm casing, a 75 mm vertical electric submersible pump is immersed to extract water. This method of extracting water from boreholes is widely employed by water vendors in Ayigya, Kumasi, Ghana.

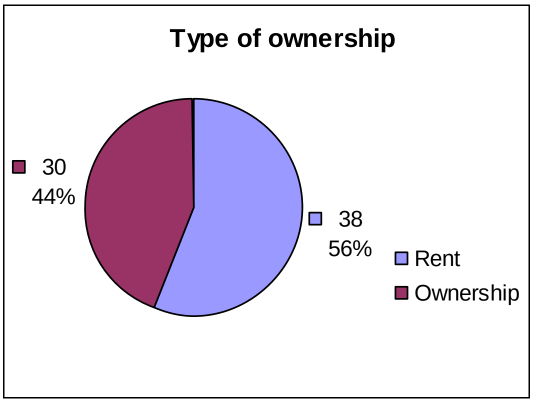
Source: Author, field work, July 2010

4.3 Techno-Financial Feasibility of Adopting Roof Top Rain Water Harvesting (RWH)

Before explaining the techno-financial feasibility of adopting household RWH in Ayigya, the researcher wishes to explain the prevailing housing conditions in Ayigya. The researcher observed that most of the houses in Ayigya are single-storied compound houses with CGI sloping roofs which are technically good for RWH. The household survey reveals that 44 per cent of the respondents live in their own house where as 56 per cent of the respondents live in rented accommodation as illustrated in table 18 below. This may mean the majority of landlords stay in the same compound house with their tenants. On the other hand, it may also mean that tenants have cordial relationships with their landlords aside from low rents. This cordial relationship between the landlords and tenants has led to a number of room extensions by the tenants with the full understanding of their respective landlords. This mutual understanding between the landlords and tenants could be mainly due to their long tenancy aside from having the same religion. Ayigya Zango is predominantly Muslim and the researcher observed a strong community bond between the inhabitants, and their Chief plays a very important role in social harmony and cohesion.

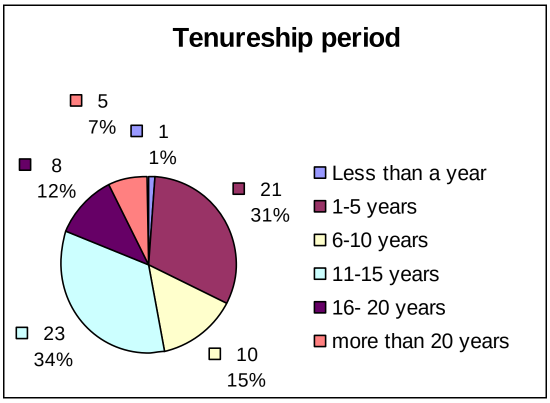
This situation could be conducive to the adoption and installation of RWH systems at the household level by tenants, due their long period of tenancy (Figure 19) and cordial relationships with their landlords. Considering the situation there, the role of the Chief is very prominent and he could be the key catalyst on any welfare issues. Extended tenancy may also prove to be an incentive for tenants to invest in RWH systems. On the other hand, a landlord may have all together a different perspective and may like to install the system considering the long term benefits.

Figure 18: Type of ownership



Source: Analysed data, field work, July 2010

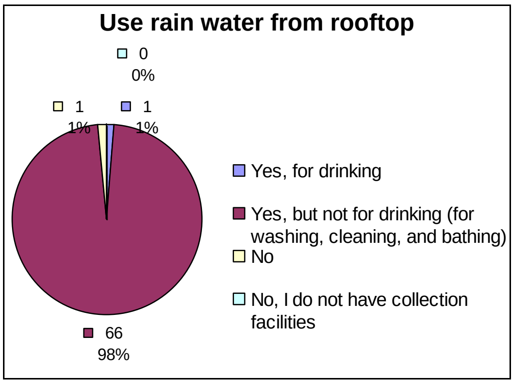
Figure 19: Tenancy period



Source: Analysed data, field work, July 2010

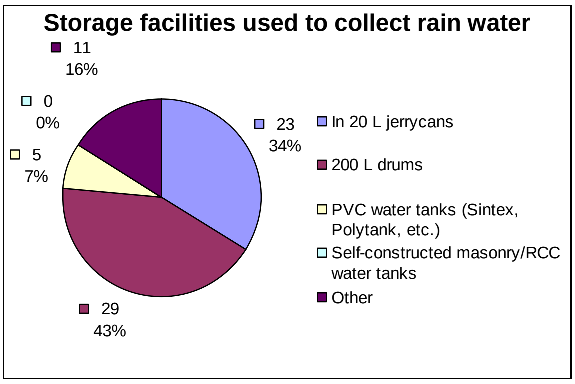
Figure 20 below illustrates that nearly 98 per cent of the respondents in Ayigya collect rainwater from rooftops for their household use which includes washing, cleaning and bathing. Another 1per cent of the respondents even use rain water for drinking after boiling whereas remaining 1 per cent do not use rainwater at all. Although they collect rainwater for their household use, only few of them have installed rainwater gutters and the majority of them collect rainwater from rooftops without any provision of gutters and proper storage tanks. The majority of them collect rainwater and store it in jerry cans, buckets, pans and 200 litres drums. Figure 21 below shows that 35 per cent of the respondents use jerry cans to collect rainwater whereas another 45 per cent use 200 liters drum to collect rain water from rooftops and only 8 per cent of the respondents use PVC water tanks.

Figure 20: Use of rain water from rooftop



Source: Analysed data, field work, July 2010

Figure 21: Storage facilities used to collect rain water



Source: Analysed data, field work, July 2010

Regarding the technical feasibility of installing individual roof top rain water harvesting system, the feasibility depends on the following components:

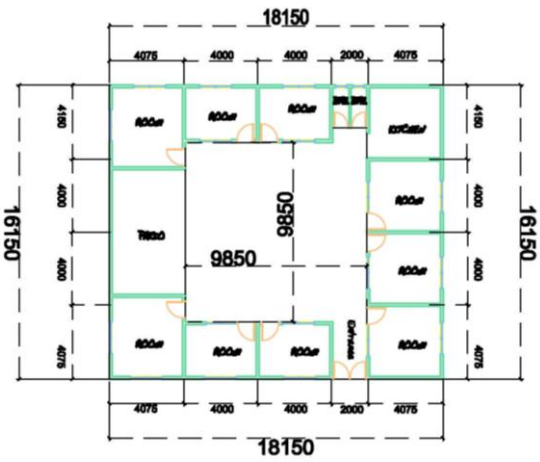
1 Type and size of roof (catchment) and roofing material used in the house;
2 Type of building materials available in local market;
3 Skilled labour and knowledge;

3 Consumption of water/ household;
4 Perception of the household on RWH;
4 Rainfall pattern;
6 Technical and Financial aspect of RWH.

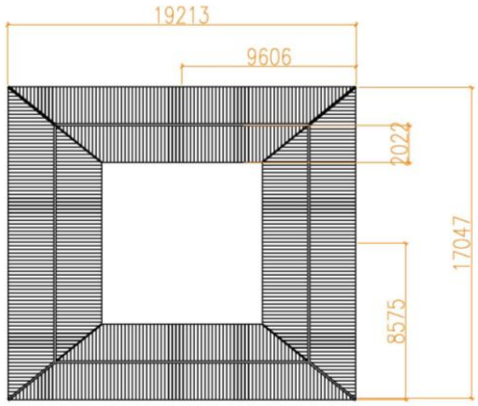
4.3.2 Type of material used in roofing

In Ayigya, the researcher observed that all the compound houses have sloping roofs with corrugated galvanized iron sheets (CGI) as roofing materials. This statement is fully supported by household survey analysis of 68 respondents, which revealed that all respondents use CGI sheets as the main roofing material. Similar to roofing materials, the researcher observed that all the compound houses in Ayigya have wooden rafters and purlins and the same is revealed by the household survey.

Figure 22: A typical plan, roof plan and elevation of a compound house in Ayigya, Kumasi



Ground Plan



Roof Plan


Front Elevation

Source: Author, drawn from field work, July, 2010

The above drawings are the typical floor plan, roof plan and elevation of a typical compound house in Ayigya. The total roof area in flat is 227.854 m^2 and therefore the total catchment area is also 227.854 m^2. The compound houses have an open to sky courtyard (11.12m x 8.98m) 99.85 m^2 in the middle of the house and all rooms are arranged around the courtyard and all doors open directly to the court yard. Generally, there is only one common entrance to a compound house. The external façade of a compound house is provided with fenestrations for ventilation and lighting. This court is used as a multi-functional space by the residents.

4.3.3 Type of building material available in local market

Figure 23: A gutter and a hold fast

Source: Author, field work, July 2010

The gutters available in the local markets in Kumasi are generally of galvanized iron sheet having a sectional size of 2”x4.5”x5” and 8’-00” in length (112x125x75 and 2400 mm long) and available in two types: with sprout 4” diameter and without sprout.

The cost of one 8’-00” long gutter is GH¢ 10 and they are provided with 2 numbers mild-steel holdfasts to enable to fit to the edge of rafters or purlins, depending on the constructional details. These steel holdfasts are provided with 1/16” holes for fastening with suitable nails or screws to the rafters or purlins and the sectional size is 4.5”x5”x2”.

Apart of galvanized gutters, painted versions are also available in local market and a hardware shop called Halfex Ent, P.O. Box-745, KNUST, Kumasi, deals with varieties of rainwater gutters including different PVC pipes. The PVC pipes are available in varieties of sizes, which include 11/2”, 2”, 4” and 6” diameters. The elbow junctions and ‘T’ junctions are also available in similar diameters. The other connection materials such as unions, valves are available in different sizes.

The table below provide a list of items along with prices of different sanitary materials (materials required in installation of rooftop RWH system) available in local market in Kumasi and labour cost in Ayigya.

Table 9: Cost of various building materials in Kumasi as on 15th July 2001

SI No.	Description of Materials	Price per Unit (GH¢)
1	11/2” diameter, 20’-00” long PVC pipe	8.50
2	2” diameter, 20’-00” long PVC pipe	8.00
3	4” diameter, 20’-00” long PVC pipe	6.50
4	6” diameter, 20’-00” long PVC pipe	45.00
5	11/2” diameter PVC elbow	00.70
6	2” diameter PVC elbow	1.20
7	4” diameter PVC elbow	2.00

8	6” diameter PVC elbow		8.00	
9	S-100 PVC pipe adhesive, 500 grams		4.50	
10	1” dia tank connector		4.00	
11	1” dia valve socket		0.60	
12	2”X 41/2” X 5” and 8’-00” long Gutter with 2 no. holdfasts		10.00	
13	3’-3”X3’-3” X3’-6” Rectangular PVC water storage tank		120.00	
15	Portland Cement 50 Kg		12.00	
16	1 cubic Meter of sand		10.00	
17	830mmX245 CGI roofing sheet		6.50	
18	200 liters PVC used drums		30.00	
19	Sand Crete 22.5X13.5X46 cm		1.00	

Source: Author, personal observation during field work, July 2010

4.3.4 Skilled labour and Knowledge

As Kumasi is the second largest town in Ghana, the researcher observed varieties of construction activities varying from traditional architecture to modern architecture. The in-depth interview with few masons and highly skilled labours reveal the following man-day charges per class of labour.

Table 10: Cost of labour in Kumasi

SI No	Class of Labour	Man-day Charge (GH¢)		
1	Highly Skilled Labour- masons, plumber, tile layers etc.		20.00	
2	Skilled Labour		13.50	
3	Semi-skilled Labour		10.50	

Source: Author, personal observation during field work, July 2010

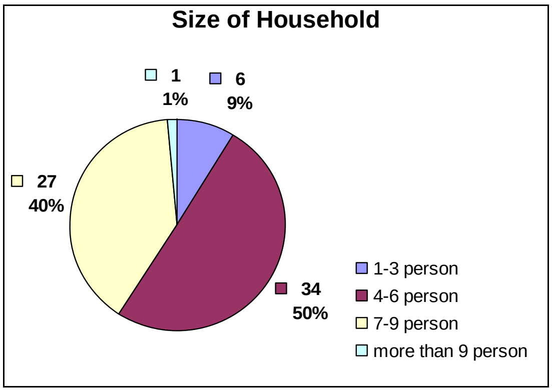
The researcher also observed that the skilled labour dealing in building construction are capable of constructing complex building designs and most of them are partially aware of building components such as gutters and holdfasts to support the gutters. They have good knowledge in the construction of storage tanks using *sandcrete* blocks and cement. Now, apart from discussing the availability of various building components and skilled labourers capable of undertaking the installation work of rooftop RWH, it is equally important to know the daily average demand of water and people’s perception of RWH in the research area in Ayigya, Kumasi. The following sections explain the existing household demand of water and their consumption pattern along with people’s perception of RWH and their acceptance of the system through the analysis of data and information collected from the household survey and in-depth interviews.

2.3.5 Consumption of water/household

According to the literature review in chapter two, the demand or water is closely related to the size of the household and the sanitation habits. According to UN-Habitat (2003) it is difficult to put a specific figure on an ‘adequate’ volume of water, but in most circumstances, at least 20 litres of water per person per day is essential. 60 liters of water per person per day is required to address domestic needs such as washing, food preparation, cooking, cleaning, laundry and personal hygiene. However, this will also depend on the type of sanitation facilities used by the household. To illustrate an example, more water will be needed if flush toilets are used by a household.

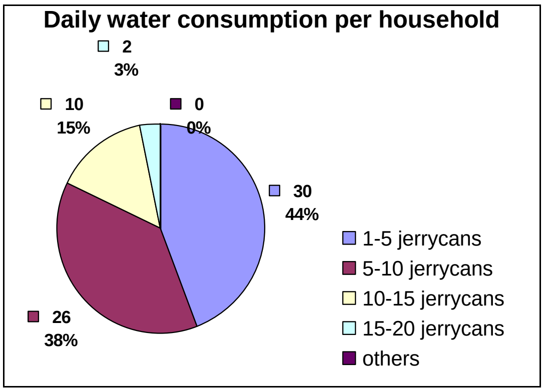
In the case of Ayigya, the researcher observed that the majority of the households do not have access to in-house sanitation facilities and depend solely on community toilets and further, the household survey reveals that the average household size is 4-6 persons as illustrated in figure 24. Regarding the consumption of water, the majority of the households consume around 5 jerry cans (100) per day. The detailed water consumption pattern is illustrated in figure 25, which verifies that 44 per cent of the respondents use 1-5 jerry cans of water daily whereas another 38 per cent use 5-10 jerry cans of water daily. Only 15 per cent of the respondents use 10-15 jerry cans per day. These figures yield a majority consumption of 20 liters per day per person which is in line with the bare minimum figure for domestic use and personal hygiene according to the literature review.

Figure 24: Size of household



Source: Analysed data, field work, July 2010

Figure 25: Daily water consumption per household



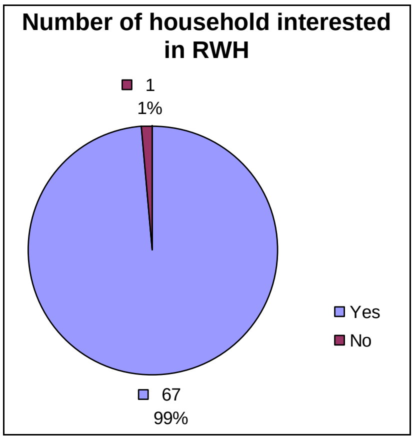
Source: Analysed data, field work, July 2010

4.3.6 Households' perception of RWH

The household survey reveals that more than 98 per cent of the respondents have already been collecting rain water from rooftops using buckets, pans, jerry cans and 200 liters drums. The analysis also reveals that 35 per cent of the respondents feel that collection of rainwater saves their expenditure on water, while 34 per cent feel that by collection of rain water, they get more water for their household use. In addition, 30 per cent feel that by collecting rain water, they save their time in water-fetching.

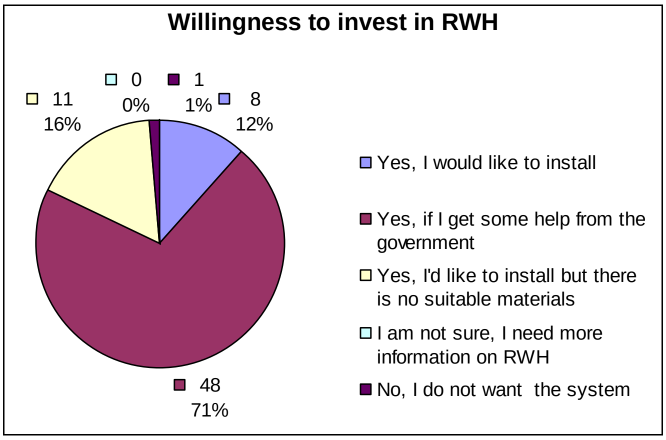
The researcher also observed that respondents are interested in rooftop RWH with proper gutters and adequate storage tanks for their individual household use. This is in relation with *stated preferences* discussed in literature review. In this regard, the researcher asks people directly what they are willing to invest/pay for goods or service in future. The survey also reveals that 99 per cent of the respondents are interested in having rooftop rain water harvesting as is illustrated in figure 26 below. Figure 27 shows that 71 per cent of the interested respondents are ready to install rooftop RWH systems provided they get some techno-financial assistance from the government. 16 per cent of the interested respondents like the system but are not fully aware of the availability of suitable materials for RWH, whereas remaining 12 per cent would like to install the system in their house at their individual level. These figures illustrate the perception of people in Ayigya on rooftop RWH. One of the major reasons for having an overwhelmingly positive response could be the already documented high expenditure on water, when compared to the alternative provided by free rainwater. Aside from the issue of cost, rainwater may prove to be a more consistent source of water than the current urban water supply, if harvested properly.

Figure 26: Number of household interested in RWH



Source: Analysed data, field work, July 2010

Figure 27: Willingness to invest in RWH



Source: Analysed data, field work, July 2010

In the following sections, the researcher looks at the techno-financial feasibility of adopting rooftop RWH considering the prevailing situation in Ayigya. The section below starts with a close and detail study on the rain fall pattern in Kumasi in the last ten years.

4.3.7 Rainfall pattern in Kumasi

At the outset in this section, the researcher looks at rainfall data of Kumasi to study the technical feasibility for collecting rainwater from rooftop. The rain fall data of Kumasi from 1985 to 2009 reveals an average annual rainfall of 1351.98 mm and for effective rain water storage calculations the researcher has used the rainfall data of last five year in Kumasi i.e. 2005 to 2009. According to the researcher's in-depth interview with the meteorological officials from Ghana Meteorological Services, Kumasi has two wet seasons in a year. The major wet season starts in February and ends in July whereas the minor season starts in September and ends in November. The Harmattan[4] period starts in Kumasi in the latter part of November and last till February.

For calculating the required volume of water storage tank, the researcher use Mass Curve Analysis Method with 5 years of rainfall data. The average annual rainfall in

[4] Harmattan is a dust-laden wind which occurs during November to March in Ghana. Source http://rdgs.dk/djg/pdfs/107/1/02.pdf [accession date at 29th August 2010 on 5.20 p.m].

Kumasi during last five year (2005 to 2009) is 1224.28mm whereas the annual rainfall from 2000 to 2004 is 1421.18mm and averages decrease is 196.9 mm during last five year. The following parameters are used to calculate the required volume of tank for storing the rainwater-

1. *Run-off coefficient*- some rain water will be lost during the collection and this amount is represented by a fraction called the run-off coefficient. Further, this value of coefficient depends on type of roof, the condition of the gutter, piping and expected evaporation from the roof and tank. In this case, as the roofing materials are all CGI, the run-off coefficient is assumed as 0.9.
2. *Monthly rain fall data of the area*- the analysis should start from the beginning of a wet season, which in this case, the researcher has adopted September.
3. *Size of the catchment area*- in this case, is the horizontal surface of the roof (not the true surface area of the roof), is used for collecting the rainwater. Further, in this research, the researcher has adopted two different catchment sizes depending on type of rain water harvesting model, which are Model-1, Model-2 and Model-3;
4. *The monthly demand of the household*- The average daily demand in Ayigya is 100 litres per household and average household size of 5 persons. This figure is derived from the household survey conducted by the researcher in Ayigya. Further, the researcher has adopted three different approaches for assuming demand based on type of Models. Model-1 is based on incremental RWH and it is capable of meeting small percentage of household water demand. However, this embryonic model is the most cost-effective and the household has the flexibility of increasing its capacity depending on the financial conditions. Model-2 caters 50 per cent uninterrupted monthly demand for the household and Model-3, although is expensive, but it is capable of providing 100 per cent uninterrupted water supply to the household throughout the year.

Table 11: Rainfall data of Kumasi, period of January 1985 to June 2010

ELEMENT: RAINFALL UNIT: mm STATION: KUMASI ASHANTI REGION

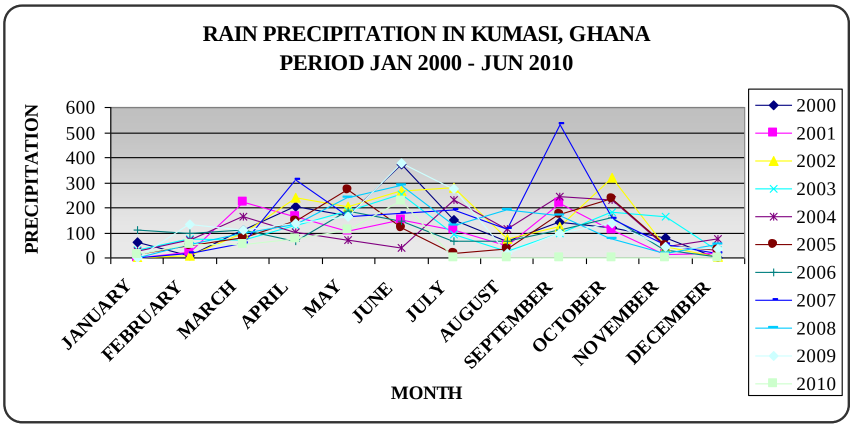
TOTAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	YEAR
1669.2	18.5	45.5	247.4	166.9	105.2	159.2	417.9	96.5	202.8	99.7	110.4	TR	1985
1232.6	TR	132.1	64.4	70.7	154.8	268	176.3	68.5	114.2	170.6	13	TR	1986
1272.4	5.9	64.8	110	171	46.3	245.9	156.8	192.1	188.7	74.4	3	13.5	1987
1520.4	TR	10	309.5	135.7	130.3	341.7	138.8	15	185.5	136.4	38.6	78.9	1988
1463.9	53.7	2.3	112.6	77.2	126.2	310.4	89.3	177	281.2	186.3	39.5	8.2	1989
1192.7	35.8	69.1	110.2	199.1	115.3	126.4	22.6	29.6	159	137.5	104.7	83.4	1990
1275.8	54.8	83.9	77.8	133.3	306.9	171.8	88.1	69.7	143.2	122.5	23.7	7.1	1991
1063.5	3.6	5.5	74.3	152.8	150.3	132.7	79.2	30.4	312.8	49.2	65.6	7.1	1992
1442	2	53.1	117.5	152.7	140	338.9	31	102.6	168	257.1	52.4	26.7	1993
1109.2	TR	7.3	52.1	194.9	208.9	116.1	96.5	63.1	156.1	179	35.2	0	1994
1327.2	0	0.7	121.6	198.8	175.8	155.1	136.6	148.5	138.8	95.7	40	115.6	1995
1040.9	3.7	80.2	72.2	111.8	145.7	106	202.7	109.6	72.5	81.8	2.8	51.9	1996
1393.4	53.7	33	138	286.7	218.7	250.2	73.4	59	96.3	162	11.1	11.3	1997
1092.2	51.8	26.6	35.9	267.4	183.3	188.7	56.5	75.6	74.7	76.5	23.5	31.9	1998
1432.8	61.3	29.5	110.2	217	101.7	217.9	202.6	114.1	135.2	204.3	39	0	1999
1488.5	62.4	7.2	110.6	206.2	168.6	373.2	153.2	65.3	144.1	119.9	77.8	0	2000

1185.8	TR	21.5	220.1	163	106.7	149.7	112.5	48.6	216.9	112.9	15.5	18.4	2001
1668	1.6	7.6	99.7	238.9	204.6	265.5	281.1	75.8	123.5	319.1	45.2	5.4	2002
1349.2	32.9	74.5	73.1	129.5	188.8	254.6	95.3	26.8	99.5	180.1	163.2	30.9	2003
1414.4	25.8	69.9	164.3	100.7	72.3	41.1	229.4	115	243.5	232.4	43.5	76.5	2004
1229	12.5	48.9	82.2	146.4	272.1	121.3	18.3	36.7	174.1	236.9	49.8	29.8	2005
1159.8	111.1	98.4	112.8	66.9	187.3	145.4	66.7	65.2	111.4	158.4	32.5	3.7	2006
1794.4	0.2	16.4	56.2	310.9	164.2	176	192.9	117.7	534.5	153.9	51.7	19.8	2007
1452	0	53.7	97.4	132	239.6	286.7	131.1	192.6	170.7	75.1	18.3	54.8	2008
1530.2	TR	131.4	110.6	139.3	164.6	376.7	273.5	17.6	99.3	138.6	45.2	33.4	2009
	14.7	52.7	52.6	77.3	108.9	225.8							2010
33799.5													

Note: TR = THE AMOUNT OF RAINFALL IS LESS THAN 0.05mm
Annual Mean Rainfall = 1351.98 mm

Source: Ghana Meteorological Services, Kumasi, 2010

Figure 28: Rain precipitation pattern in Kumasi (2000-June 2010)



Source: Analysed data, field work, July 2010

The above figure 28 and table 11 illustrate the monthly precipitation in Kumasi in last ten years which shows and average annual rainfall of 1350 mm.

4.3.8 Technical and Financial aspect of RWH

In this section, using the above monthly precipitation (2005-2009) data, the researcher makes an attempt to calculate the technical and financial feasibility for adopting three different models of RWH, considering the parameters such as size of catchment area, run-off coefficient, and average household requirement of water derived from field survey and their financial implications.

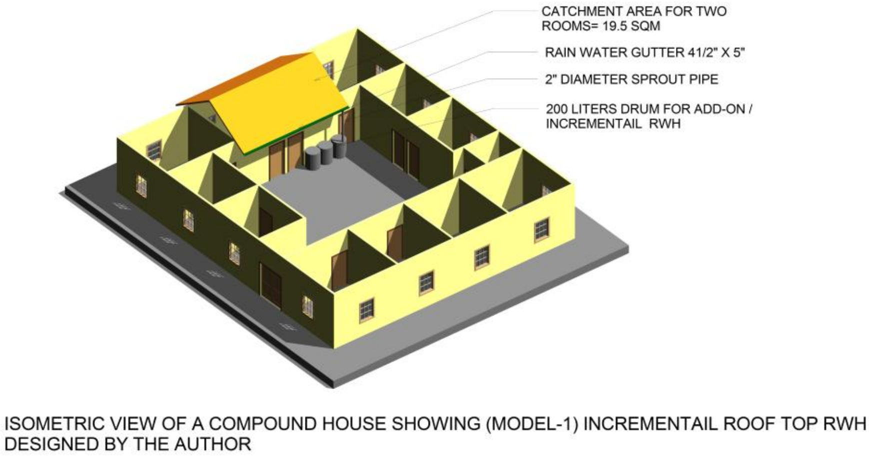
4.3.8.1 Calculation for MODEL-1 (Incremental RWH)

In this model, only a small percentage of water is provided by this system in the initial stage due to limited storage capacity 600 liters and limited initial investment. However, the household has the flexibility of adding more storage tanks to increase the rain water storage capacity. By increasing storage capacity incrementally, it can provide uninterrupted water supply to the household throughout the year. Another advantage of this model is the flexibility in installation and un-installation. This model could be very interesting and useful for tenants because of the low initial investment and durability.

Key Variables

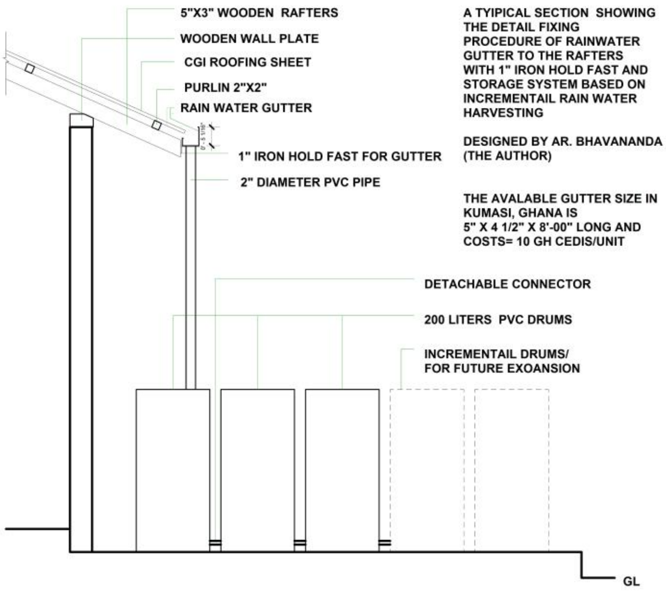
Monthly supply= area x run-off coefficient x average x monthly rainfall	
Average daily household water consumption in Ayigya (field survey)	100 litres
Annual consumption of water per household in Ayigya	36500 liters
Targeted monthly supply of water from RWH (initial 600 liters x 2 times a month)	1200 liters
Targeted annual supply of water from RWH [1200x(12- 3 months Harmattan period)]	9600 liters
% of demand met from incremental RWH (9600/36500)	26%
Run-off coefficient (roofing material – CGI sheet)	0.9
Total size of the roof	227.85 m^2
Average roof size for two rooms (only lean to side towards courtyard)	19.50 m^2

Figure 29: Design for Model-1 (Incremental Rain water Harvesting)



Source: Author, based on analysis, July 2010

Figure 30: Section of RWH installation model-1



Source: Author, based on analysis, July 2010

Table 12: Estimate for Model-1

BILL OF QUANTITY FOR CONSTRUCTION OF INCREMENTAL RWH USING 200 LITERS DRUM (INITIAL CAPACITY=600 LITERS)						
No		**Description of Work and Materials**	**Unit**	**Quantity**	**Price/Unit (GH¢)**	**Amount (GH¢)**
1	**Storage tank preparation**					**99.20**
	a	Storage tank (200 L drum)	No	3	30.00	90.00
	b	75mm tank connector	No	2	4.00	8.00
	c	Valve socket	No	2	0.60	1.20
2	**Gutter pipe**					**34.50**
	a	Gutter pipe 4.5inch x 5inch x 3 inch x 8 feet (112X125X75 and 2400 mm long)	No	3	10.00	30.00
	b	PVC rain water pipe fixed to sprout (dia. 50 mm, 6 m long)	No	1	4.50	4.50
3	**Labour cost**					**13.50**
	a	Labour cost for installation of tank, gutter pipe, and intermediate connection	man-day	1	13.50	13.50
	Total cost construction and materials					138.00
	Contingencies charges 5%					6.90
	Total cost				GH¢	**147.20**

Table 13: Payback period & NPV calculation for Incremental RWH Model

Annual Financial Saving Calculation		
Present expenditure on water per household per day in Ayigya	0.8	(GH¢)
Present expenditure on water per household per month	24	(GH¢)
Annual expenditure on water per household	288	(GH¢)
Annual Saving (Assumption: 26 % of water demand met by RWH)	74.8	(GH¢)
Payback period = Construction cost/saving	1.96	Years
		Say 2 years
Annual Economic Saving Calculation (Related to time saving in fetching water)		
Man-day unskilled labour cost	10.50	(GH¢)
Cost of 1 hour working (10.5/8)	1.31	(GH¢)
Economic cost on water fetching per person per day (assumption: 30min)	0.66	(GH¢)
Economic cost on water fetching per person per month	19.69	(GH¢)
Economic cost on water fetching per person per year	236.25	(GH¢)
Annual Saving (Assumption: 26 % of water demand met by RWH)	61.42	(GH¢)
Total saving per year by RWH (Financial + economic)	**136.22**	**(GH¢)**
Payback period = Construction cost/total saving	**1.08**	**years**
		say, 1 year 1 month
Calculation for Net Present Value (NPV) $NPV = \frac{\sum CFi}{(1+r)^n} - I_t$ *CFi= cash inflow, I_t= Initial outlay*		
Initial total investment in RWH system	147.20	(GH¢)
Annual rate of interest in percentage	10%	
Annual return on the investment	136.22	(GH¢)
(136.22/1.1) + (136.22/1.21= 123.83+112.57	236.40	(GH¢)
NPV >1 (236.40-147.20)	**+ 89.20**	**Accept**
Since the NPV is positive on the 2nd year, this project can be taken up		

4.3.8.2 Calculation for MODEL-2 (50% supply from RWH)

The calculation for model-2 is based on rain fall data from 2005 to 2009 and half of the catchment area of two rooms i.e. 19.5m^2. In this model, 50 per cent of the daily household water demand is to be met from RWH. In the following sections, the researcher calculates the size of the required water storage tank by using ***Mass Curve Analysis.***

Key Variables

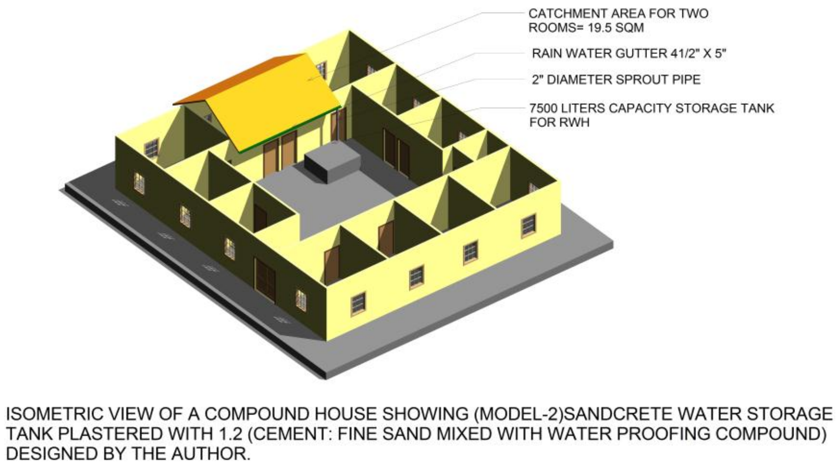
Monthly supply= area x run-off coefficient x average x monthly rainfall	
Average daily household water consumption in Ayigya (field survey)	100 litres
Targeted supply of water from RWH (50% daily consumption- un interrupted)	50 litres
Run-off coefficient (roofing material – CGI sheet)	0.9
Total size of the roof	227.85 m^2
Average roof size for two rooms (only lean to side towards courtyard)	19.50 m^2

Table 14: Mass Curve Analysis for model-2

MONTH	Monthly Precipitation (MM)	Monthly Supply (L)	Cummulative Supply (L)	Monthly Demand (L)	Water Deposit (L)	Cummulative Water Deposit (L)	YEAR	Required Tank Volume
SEPTEMBER	243.5	4273	4273	1500	2773	2773	2004	
OCTOBER	232.4	4079	8352	1500	2579	5352		
NOVEMBER	43.5	763	9115	1500	-737	4615		
DECEMBER	76.5	1343	10458	1500	-157	4458		
JANUARY	12.5	219	10677	1500	-1281	3177	2005	
FEBRUARY	48.9	858	11536	1500	-642	2536		
MARCH	82.2	1443	12978	1500	-57	2478		
APRIL	146.4	2569	15548	1500	1069	3548		
MAY	272.1	4775	20323	1500	3275	6823		
JUNE	121.3	2129	22452	1500	629	7452		
JULY	18.3	321	22773	1500	-1179	6273		
AUGUST	36.7	644	23417	1500	-856	5417		4973
SEPTEMBER	174.1	3055	26472	1500	1555	6972		
OCTOBER	236.9	4158	30630	1500	2658	9630		
NOVEMBER	49.8	874	31504	1500	-626	9004		
DECEMBER	29.8	523	32027	1500	-977	8027		
JANUARY	111.1	1950	33977	1500	450	8477	2006	
FEBRUARY	98.4	1727	35704	1500	227	8704		
MARCH	112.8	1980	37683	1500	480	9183		
3APRIL	66.9	1174	38857	1500	-326	8857		
MAY	187.3	3287	42145	1500	1787	10645		
JUNE	145.4	2552	44696	1500	1052	11696		
JULY	66.7	1171	45867	1500	-329	11367		
AUGUST	65.2	1144	47011	1500	-356	11011		4724
SEPTEMBER	111.4	1955	48966	1500	455	11466		
OCTOBER	158.4	2780	51746	1500	1280	12746		
NOVEMBER	32.5	570	52317	1500	-930	11817		

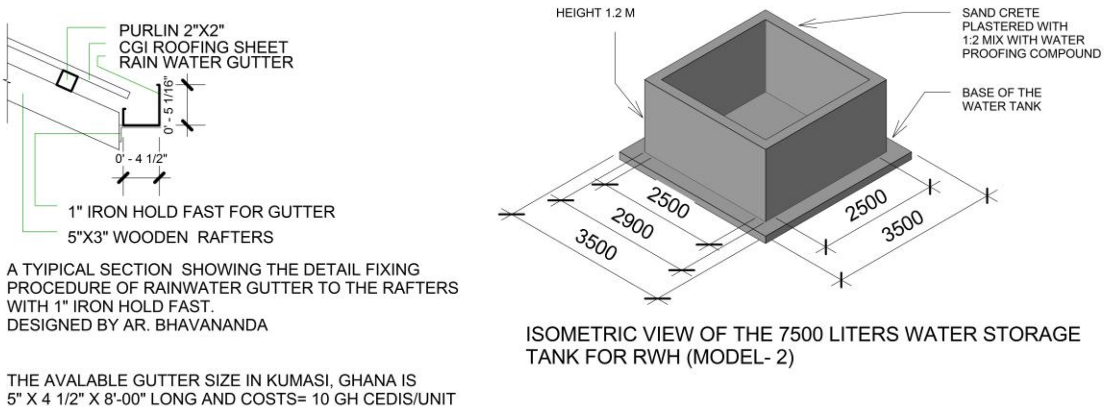
DECEMBER	3.7	65	52381	1500	-1435	10381		
JANUARY	0.2	4	52385	1500	-1496	8885	2007	
FEBRUARY	16.4	288	52673	1500	-1212	7673		
MARCH	56.2	986	53659	1500	-514	7159		
APRIL	310.9	5456	59115	1500	3956	11115		
MAY	164.2	2882	61997	1500	1382	12497		
JUNE	176	3089	65086	1500	1589	14086		
JULY	192.9	3385	68471	1500	1885	15971		
AUGUST	117.7	2066	70537	1500	566	16537		9378
SEPTEMBER	534.5	9380	79917	1500	7880	24417		
OCTOBER	153.9	2701	82618	1500	1201	25618		
NOVEMBER	51.7	907	83526	1500	-593	25026		
DECEMBER	19.8	347	83873	1500	-1153	23873		
JANUARY	0	0	83873	1500	-1500	22373	2008	
FEBRUARY	53.7	942	84816	1500	-558	21816		
MARCH	97.4	1709	86525	1500	209	22025		
APRIL	132	2317	88842	1500	817	22842		
MAY	239.6	4205	93047	1500	2705	25547		
JUNE	286.7	5032	98078	1500	3532	29078		
JULY	131.1	2301	100379	1500	801	29879		
AUGUST	192.6	3380	103759	1500	1880	31759		9943
SEPTEMBER	170.7	2996	106755	1500	1496	33255		
OCTOBER	75.1	1318	108073	1500	-182	33073		
NOVEMBER	18.3	321	108394	1500	-1179	31894		
DECEMBER	54.8	962	109356	1500	-538	31356		
JANUARY	0	0	109356	1500	-1500	29856	2009	
FEBRUARY	131.4	2306	111662	1500	806	30662		
MARCH	110.6	1941	113603	1500	441	31103		
APRIL	139.3	2445	116048	1500	945	32048		
MAY	164.6	2889	118936	1500	1389	33436		
JUNE	376.7	6611	125547	1500	5111	38547		
JULY	273.5	4800	130347	1500	3300	41847		
AUGUST	17.6	309	130656	1500	-1191	40656		11992
SEPTEMBER	99.3	1743	132399	1500	243	40899		
OCTOBER	138.6	2432	134831	1500	932	41831		
NOVEMBER	45.2	793	135625	1500	-707	41125		
DECEMBER	33.4	586	136211	1500	-914	40211		
JANUARY	14.7	258	136469	1500	-1242	38969	2010	
FEBRUARY	52.7	925	137394	1500	-575	38394		
MARCH	52.6	923	138317	1500	-577	37817		
APRIL	77.3	1357	139673	1500	-143	37673		
MAY	108.9	1911	141585	1500	411	38085		
JUNE	225.8	3963	145547	1500	2463	40547		4158
	Average mean size for the water storage tank							**7528**
Notes:	This calculation is based on 50% of daily water demand to be met from RWH.							
Catchment Area		$19.5M^2$						
Run-off Coefficient		0.9						
Demand/family/day		100	50 per cent to be met from RWH.					

Figure 31: Design for Model-2 (50% demand i.e. 7528 liters to be met from RWH)



Source: Author, based on analysis, July 2010

Figure 32: Sectional details of gutter and isometric view of storage tank



Source: Author, based on analysis, July 2010

The researcher calculates the size of the water storage tank as 7528 litres and the drawing above shows the dimensions of the storage tank. The tank is to be prepared by using *sandcretes* in 1:2 cement mortars. The cement mortar should be mixed with water proofing compound following the specifications of the manufacturer. The walls of the tank should be plastered with 20 mm thick cement and fine sand plaster. The gutter should be fixed to existing rafters or to facia boards depending on the existing construction details. Figure 32 above illustrates a typical gutter fixing detail using steel holdfasts.

The rainwater sprout of the gutter should be connected with 50mm diameter and 1500mm long PVC pipe to channel the rain water to the storage tank. The following tables show the bill of materials along with the total cost of the system and NPV, payback period calculations.

Table 15: Estimate of quantity for Model-2

BILL OF QUANTITY FOR CONSTRUCTION OF 7500 LITERS WATER STORAGE TANK+INSTALATION OF RWH SYSTEM						
No		**Description of Work and Materials**	**Unit**	**Quantity**	**Price/Unit (GH¢)**	**Amount (GH¢)**
1	**Storage tank preparation:**					**464.75**
	a	Earth work excavation (3.5m x 3.5m x 1m)	M³	12.25	3.00	36.75
	b	Concrete blocks for perimeter and base	Block	243	1.00	243.00
		(dimension 46cm x 22.5cm x 11.5cm)				
	c	Cement (50 Kg bag, mix 1:2)	Bag	14	12.50	175.00
		(assumption: 1 bag for 25 concrete and 4 bags for plaster)				
	d	Sand (coarse + fine)	M³	1	10.00	10.00
2	**Gutter pipe**					**34.50**
	a	Gutter pipe 4.5inch x 5inch x 3 inch x 8 feet	No.	3	10.00	30.00
		(112X125X75 and 2400 mm long)				
	b	PVC rain water pipe (dia. 100 mm, 6 m long)	No.	1	4.50	4.50
3	**Labour cost**					**54.00**
	a	Labour cost for water storage tank construction & gutter installations	man-day	4	13.50	54.00
	Total cost construction (materials+ Labour)					553.25
	Contingencies charges 5%					27.66
	Total cost				GH¢	**580.91**

Table 16: Payback period calculation for Model-2

Annual Financial Saving Calculation		
Present expenditure on water per household per day in Ayigya	0.8	(GH¢)
Present expenditure on water per household per month	24	(GH¢)
Annual expenditure on water per household	288	(GH¢)
Annual Saving (Assumption: 50% of water demand met by RWH)	144	(GH¢)
Payback period = Construction cost/saving	4.03	Years
	or, 4 years 1 months	

Annual Economic Saving (Related to time saving in fetching water)		
Man-day un-skilled labour cost	10.50	(GH¢)
Cost of 1 hour working (10.5/8)	1.31	(GH¢)
Economic cost on water fetching per person per day (assumption: 30min)	0.66	(GH¢)
Economic cost on water fetching per person per month	19.69	(GH¢)
Economic cost on water fetching per person per year	236.25	(GH¢)
Annual Saving (Assumption: 50% of water demand met by RWH)	118.13	(GH¢)
Total saving per year by RWH (Financial + economic)	**262.13**	**(GH¢)**
Payback period = Construction cost/total saving	**2.22**	**years**
	or, 2 years 3 months	

Table 17: NPV calculation for Model-2

Calculation for NPV				
		Initial total investment in RWH system	580.91	(GH¢)
		Annual rate of interest in percentage	10%	
		Annual return on the investment	262.13	(GH¢)
		(262.13/1.1)+(262.13/1.21)+(262.13/1.33) = =238.30+216.63+197)	651.93	
		NPV>1 (651.93 - 580.91)	+71.02	**Accept**
		Since the NPV is positive on the 3rd year, this project can be taken up		

4.3.8.3 Calculation for MODEL-3 (100% supply from RWH)

Although, this model is a bit expensive, but it is capable of providing uninterrupted water supply to the household from rainwater throughout the year. The initial investment is comparatively higher than previous models but rate of return is also equally high because of full saving in expenditure on water. The cost of annual maintenance is negligible compare to benefits. The total cost of the system is GH¢ 789.58 and the payback period is only 1 year 6 months and annual total economic and financial saving is GH¢ 524.25. The detail calculations are illustrated below along with detail design of the model.

Key Variable

Monthly supply= area x run-off coefficient x average x monthly rainfall	
Average daily household water consumption in Ayigya (field survey)	100 litres
Targeted supply of water from RWH (100% daily consumption)	100 litres
Run-off coefficient (roofing material – CGI sheet)	0.9
Total size of the roof	227.85 m^2
Average roof size for two rooms (both sides of the roof)	39 m^2

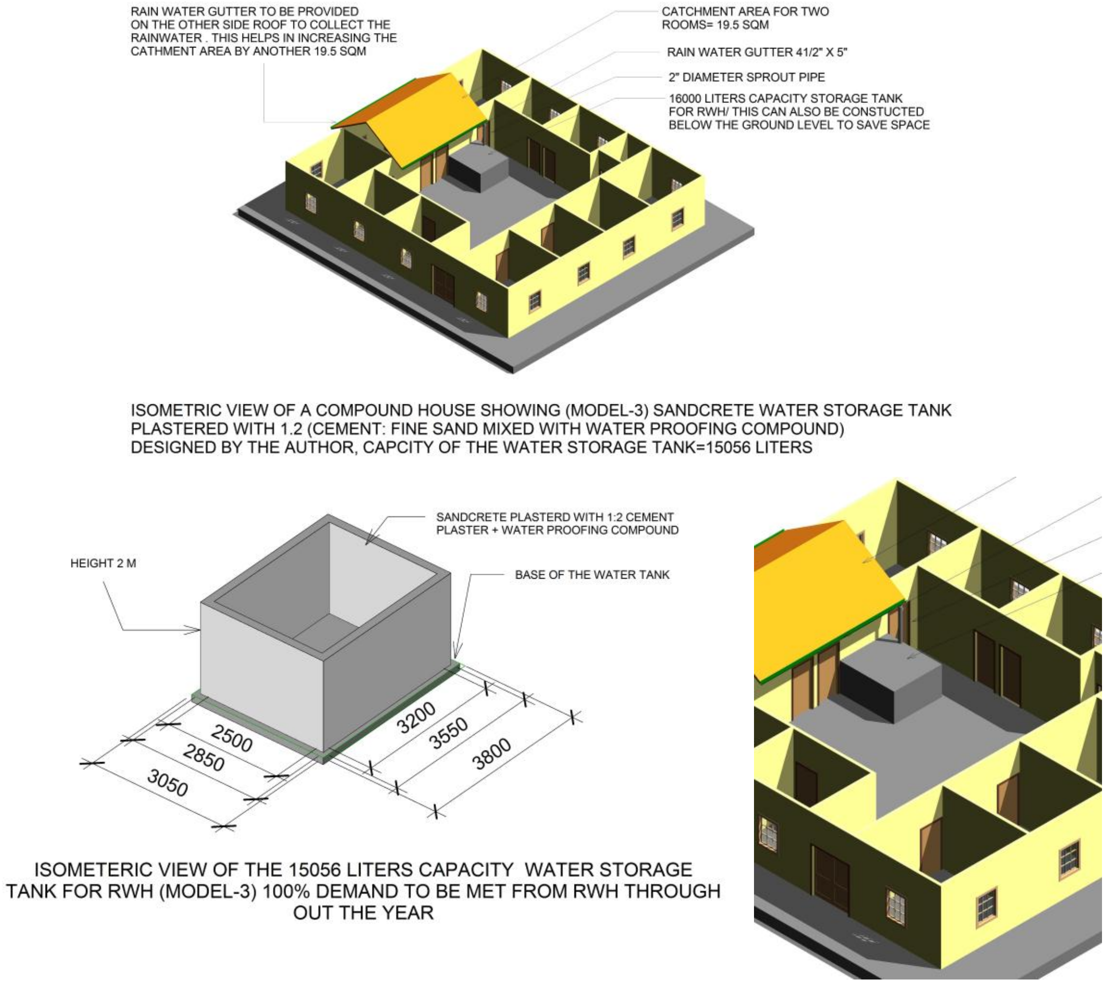
Table 18: Calculation of required tank volume for RWH installation model-3

MONTH	Monthly Precipitation (MM)	Monthly Supply (L)	Cummulative Supply (L)	Monthly Demand (L)	Water Deposit (L)	Cummulative Water Deposit (L)	YEAR	Required Tank Volume
SEPTEMBER	243.5	8547	8547	3000	5547	5547	2004	
OCTOBER	232.4	8157	16704	3000	5157	10704		
NOVEMBER	43.5	1527	18231	3000	-1473	9231		
DECEMBER	76.5	2685	20916	3000	-315	8916		
JANUARY	12.5	439	21355	3000	-2561	6355	2005	
FEBRUARY	48.9	1716	23071	3000	-1284	5071		
MARCH	82.2	2885	25956	3000	-115	4956		
APRIL	146.4	5139	31095	3000	2139	7095		
MAY	272.1	9551	40646	3000	6551	13646		
JUNE	121.3	4258	44903	3000	1258	14903		

JULY	18.3	642	45546	3000	-2358	12546		
AUGUST	36.7	1288	46834	3000	-1712	10834		9947
SEPTEMBER	174.1	6111	52945	3000	3111	13945		
OCTOBER	236.9	8315	61260	3000	5315	19260		
NOVEMBER	49.8	1748	63008	3000	-1252	18008		
DECEMBER	29.8	1046	64054	3000	-1954	16054		
JANUARY	111.1	3900	67954	3000	900	16954	2006	
FEBRUARY	98.4	3454	71407	3000	454	17407		
MARCH	112.8	3959	75367	3000	959	18367		
APRIL	66.9	2348	77715	3000	-652	17715		
MAY	187.3	6574	84289	3000	3574	21289		
JUNE	145.4	5104	89393	3000	2104	23393		
JULY	66.7	2341	91734	3000	-659	22734		
AUGUST	65.2	2289	94022	3000	-711	22022		9448
SEPTEMBER	111.4	3910	97933	3000	910	22933		
OCTOBER	158.4	5560	103492	3000	2560	25492		
NOVEMBER	32.5	1141	104633	3000	-1859	23633		
DECEMBER	3.7	130	104763	3000	-2870	20763		
JANUARY	0.2	7	104770	3000	-2993	17770	2007	
FEBRUARY	16.4	576	105346	3000	-2424	15346		
MARCH	56.2	1973	107318	3000	-1027	14318		
APRIL	310.9	10913	118231	3000	7913	22231		
MAY	164.2	5763	123994	3000	2763	24994		
JUNE	176	6178	130172	3000	3178	28172		
JULY	192.9	6771	136943	3000	3771	31943		
AUGUST	117.7	4131	141074	3000	1131	33074		18756
SEPTEMBER	534.5	18761	159835	3000	15761	48835		
OCTOBER	153.9	5402	165237	3000	2402	51237		
NOVEMBER	51.7	1815	167051	3000	-1185	50051		
DECEMBER	19.8	695	167746	3000	-2305	47746		
JANUARY	0	0	167746	3000	-3000	44746	2008	
FEBRUARY	53.7	1885	169631	3000	-1115	43631		
MARCH	97.4	3419	173050	3000	419	44050		
APRIL	132	4633	177683	3000	1633	45683		
MAY	239.6	8410	186093	3000	5410	51093		
JUNE	286.7	10063	196156	3000	7063	58156		
JULY	131.1	4602	200758	3000	1602	59758		
AUGUST	192.6	6760	207518	3000	3760	63518		19887
SEPTEMBER	170.7	5992	213510	3000	2992	66510		
OCTOBER	75.1	2636	216146	3000	-364	66146		
NOVEMBER	18.3	642	216788	3000	-2358	63788		
DECEMBER	54.8	1923	218712	3000	-1077	62712		
JANUARY	0	0	218712	3000	-3000	59712	2009	
FEBRUARY	131.4	4612	223324	3000	1612	61324		
MARCH	110.6	3882	227206	3000	882	62206		
APRIL	139.3	4889	232095	3000	1889	64095		
MAY	164.6	5777	237873	3000	2777	66873		
JUNE	376.7	13222	251095	3000	10222	77095		
JULY	273.5	9600	260695	3000	6600	83695		

AUGUST	17.6	618	261312	3000	-2382	81312		23983
SEPTEMBER	99.3	3485	264798	3000	485	81798		
OCTOBER	138.6	4865	269663	3000	1865	83663		
NOVEMBER	45.2	1587	271249	3000	-1413	82249		
DECEMBER	33.4	1172	272422	3000	-1828	80422		
JANUARY	14.7	516	272938	3000	-2484	77938	2010	
FEBRUARY	52.7	1850	274787	3000	-1150	76787		
MARCH	52.6	1846	276634	3000	-1154	75634		
APRIL	77.3	2713	279347	3000	-287	75347		
MAY	108.9	3822	283169	3000	822	76169		
JUNE	225.8	7926	291095	3000	4926	81095		8316
	Average mean size for the water storage tank							**15056**
Notes:	This calculation is based on 100% of daily water demand to be met from RWH with wider catchment area							
Catchment Area		39		11268				
Run-off Coefficient		0.9						
Demand/family/day		100	100 per cent demand to be met from RWH					

Figure 33: Design for Model-3 (100% demand i.e. 15000 liters to be met from RWH)



Source: Author, based on analysis, July 2010

Table 19: Estimate of quantity for Model-3

BILL OF QUANTITY FOR CONSTRUCTION OF 15,056 LITERS WATER STORAGE TANK + INSTALATION OF RWH SYSTEM						
No		**Description of Work and Materials**	**Unit**	**Quantity**	**Price/Unit (GH¢)**	**Amount (GH¢)**
1		**Storage tank preparation**				**591.20**
	a	Earth work excavation (3.5m x 2.7m x 2m)	M³	18.90	3.00	56.70
	b	Sandcretes for perimeter walls and base	Block	323	1.00	323.00
		(dimension 46cm x 22.5cm x 11.5cm)				
	c	Cement (50 Kg bag, mix 1:2)	Bag	17	12.50	211.50
		(assumption:. 1 bag for 25 Sandcretes and 4 bags for plastering the inside and outside the tank)				
	d	Sand (coarse + fine)	M³	1.5	10.00	15.00
2		**Gutter pipe**				**63.25**
	a	Gutter pipe 4.5inch x 5inch x 3 inch x 8 feet	No.	5	10.00	50.00
		(112X125X75 and 2400 mm long)				
	b	PVC rain water pipe (dia. 100 mm, 6 m long)	No.	1	6.50	6.50
	c	Elbow (dia. 100mm)	No.	2	2.00	4.00
	d	PVC rain water pipe fix to sprout (dia. 50 mm, 2 m long)	No.	1	2.75	2.75
3		**Labour cost**				**135.00**
	a	Labour cost for installation of tank, gutter pipe and connections	man-day	10	13.50	135.00
		Total cost **construction** and **materials**				254.95
		Contingencies charges 5%				12.75
		Total cost			GH¢	**789.45**

Table 20: Payback period calculation for model-3

Annual Financial Saving Calculation		
Present expenditure on water per household per day in Ayigya	0.8	(GH¢)
Present expenditure on water per household per month	24	(GH¢)
Annual expenditure on water per household	288	(GH¢)
Annual Saving (Assumption: 100% of water demand met by RWH)	288	(GH¢)
Payback period = Construction cost/saving	2.74	Years
or, 2 years 8 months		
Annual Economic Saving (Related to time saving in fetching Water)		
Man-day unskilled labour cost	10.50	(GH¢)
Cost of 1 hour working (10.5/8)	1.31	(GH¢)
Economic cost on water fetching per person per day (assumption: 30min)	0.66	(GH¢)
Economic cost on water fetching per person per month	19.69	(GH¢)
Economic cost on water fetching per person per year	236.25	(GH¢)
Annual Saving (Assumption: 100% of water demand met by RWH)	236.25	(GH¢)
Total saving per year by RWH (Financial + economic)	**524.25**	**(GH¢)**
Payback period = Construction cost/total saving	**1.51**	**years**
or, 1 years 6 months		

Table 21: NPV calculation for model-3

Calculation for Net Present Value (NPV)				
		Initial total investment in RWH system	789.45	(GH¢)
		Annual rate of interest in percentage	10%	
		Annual return on the investment	524.25	(GH¢)
		(524.25/1.1)+(524.25 /1.21= 476.59+433.26	909.85	(GH¢)
		NPV >1 (909.85-789.45)	**120.40**	**Accept**
		Since the NPV is positive in 2nd year, this project can be taken up		

The three models of Rain Water Harvesting system illustrated above show different options a household could employ in practicing RWH at micro-level. Model-1 is the cheapest of all models and it cost only GH¢ 147.20 and from technical perspective, it is the easiest to install and un-install. However this model can provide a small quantity of water to the household. Considering the total investment, household can easily install this model and keep on increasing the storage capacity to meet their demand depending on their financial capacity. Model-2 aims at meeting at least 50 per cent of household water demand through rainwater harvesting. Model-3 is capable of providing 100 per cent household water demand from RWH, although the initial investment is comparatively higher than other models. The payback period for this model is very low due high saving in expenditure on water. The payback period for this model is only 1 year 6 months. Any household employing this model can get back their capital investment in the aforesaid period.

Chapter 5: Conclusions and recommendations

This research has analysed the potential of rainwater harvesting in Ayigya, Kumasi, Ghana with an objective to examine issues related to potable water provision in Ayigya and to identify the problems and potential options related to it, in order to improve the well-being of people in Ayigya.

In order to achieve the above objective, data were collected through Survey, and Archival and analysed using both qualitative and quantitative methods

5.1 Conclusion

The main findings drawn from the above study are:

1. Formal Piped Water Supply

- The existing water supply situation in Ayigya from Ghana Water Company is not very satisfactory. The research revealed only 23 GWCL piped water connections in the research area and 19 of them were water vendors. This illustrates a very low ratio compared to the population. Even though Barikese Water treatment Plant was upgraded (2007-2009) by spending 37 million Euros, there is still huge gap between demand and supply of water in Kumasi.
- By the end of 2010, Owabi and Barikese are expected to produce 102,060 m^3 /day and demand and supply gap will be 21,226 m^3 /day. But this demand and supply gap is projected to increase to 54,143 m^3/ Day by 2015. On the other hand, both WTPs have technical limitation in further increase in their installed capacities. This will also have an indirect impact on the low-income water stressed settlements.
- The PPP between GWCL and Vitens although has improved the revenue collection and quality of service and has increased the number of disconnected customers due to non-payment. However, it has failed to extend its network to low-income settlements due to commercial considerations. Further, there has been an increase in water tariffs from 1st of June, 2010 and cost of one unit (10,000 liters) is GH¢0.80 for Domestic and GH¢ 1.80 for commercial consumers.

2. Informal water supply by ASPs

- 91 per cent of the household in the research area in Ayigya have access to water from water vendors/neighbour sellers. The average household expenditure on water is nearly GH¢ 0.8 per day and their daily water consumption is around 100 liters (5 jerry cans). The price of one jerry can of water in Ayigya in July, 2010 is GH¢ 0.10, which is 6.25 times higher than water utilities and quality is fair. However, the researcher's evaluation is below average. It is also pertinent to mention that price of one jerry can of water may cost GH¢ 0.15 in the near future due to GWCL's increased water tariff.

- The water vendors/neighbour sellers in Ayigya generally get their supply from GWCL and have individual boreholes as a supplementary source for their business. The bore holes are around 26M in depth and employs vertical submersible pump to extract the ground water. The extracted water along with piped water from GWCL is jointly stored in a common water storage tank. This coping strategy is employed by water vendors due to intermittent water supply from GWCL.
- Complaints on hiked water tariff along with irregular supply with frequent water shortages are quite common. Residents and water vendors who have water connections often complain that water does not flow at all during the day. Typically, it flows at night from 10pm to 5am in the morning. In addition to the intermittent daily supply, water often flows for only a few days a week. However, there has been a slight improvement since March, 2010. Further, most of the vendors are concerned about the increased water tariff and will ultimately affect the end users.

3. Techno-financial feasibility of RWH

- It was found that 98 per cent of the respondents have been collecting rain water for their household use during the wet seasons. However, they were collecting the water from rooftops without gutters and adequate storage facilities. It was further found that 99 per cent of the respondents were interest in installing roof top RWH system and out of which 71 per cent of them were interested in the system provided they get some techno-financial assistance from the government, 16 per cent were interested but not fully aware of the availability of suitable components and remaining 12 per cent were willing to invest at their individual level.
- In the technical aspect, it was found that the housing construction type and roofing materials used in Ayigya are suitable to adopting the RWH system although most of the CGI roofs are old. The rooftop RWH system appears to be the most appropriate technology for harvesting rainwater. Aside from this, it was found that various building components and skilled labourer required during the installation of RWH system are all available in the local market.
- This thesis has also examined the rainfall data of Kumasi in order to study the feasibility and was found that Kumasi has sufficient rainfall throughout the year except in few particular months. The rainfall data of the last five years was used to calculate the required tank volume for RWH in Ayigya using the Mass Curve Analysis Method and three most suitable volumes were calculated for storing rain to meet the daily household demand.
- In the financial aspect, the three models have their own advantages and disadvantages. The financial analysis of all models revealed that Model-1 i.e. the incremental RWH system could be installed at a relatively low cost although the initial yield capacity is low. Since it is incremental, the household has the advantage of increasing the storage capacity to achieve uninterrupted supply from the system. Model-2 has the capacity to meet 50 per cent of the household water demands from RWH at a moderate rate, whereas Model-3 provides 100 per cent of water demand for the household

throughout the year. This model is comparatively costlier than the previous models on financial terms; however, the payback period is the reasonably short due to high annual rate of return but this model requires larger space.

Table 22: Comparison between models

Type	Water storage capacity	Initial investment	Payback period in years	Cost/ litre GH¢	Remarks
Model 1	600 liters	GH¢ 147.20	1.1	0.245	Incremental, cheap but cannot provide uninterrupted supply.
Model-2	7528 liters	GH¢ 580.91	2.22	0.077	50 per cent un interrupted supply, requires large storage space, costly.
Model-3	15056 liters	GH¢ 789.45	1.51	0.052	100 per cent un interrupted supply, requires very large storage space, may not be suitable to install in open to sky courtyard. The tank can be partially below the ground level to save space but requires a pump for extracting water from the tank which can be costly.

5.2 Recommendation

From the above findings, the following suggestions are derived-

- The finding indicated that RWH can serve as a better option in minimizing the problems of household water supply. It is, therefore, imperative to launch rainwater water harvesting policy which would work in cooperation with Ministry of Water Resources Works and Housing.
- A National Network on Building centre can be established at district levels under Ministry of Water Resources Works and Housing (MWRH) in order to transfer the policy of sustainable and cost-effective technologies to grass-root level. These centres should be run by dedicated and qualified professionals related to building components and technologies.
- Some pilot projects for using all three models of RWH can be initiated by these centres in collusion with NGOs and CBOs at district level as examples with financial assistance from MWRH to make the people aware of the system and its advantages. This will also require a constant monitoring of all three systems in terms of quantity of water, quality of water, periodic maintenance and user friendliness. This will help in establishing the best suitable model to be adopted at a larger scale.
- In the case of Ayigya, it is recommended that pilot project be installed at the Mosque, which is centrally located in the middle of the neighbourhood.
- The government should combine RWH policy with National Shelter Strategy of Ghana and instruct the financial institutions such as HFC Bank, Eco Bank to facilitate micro-finance to low-income households who are interested in RWH without much restriction on eligibility criteria in order to promote RWH at household level.

- Last but not least, this study focused mainly on the techno-financial feasibility of adopting RWH at household level. It is pertinent to mention that the quality of rainwater collected from the roof tops might not be sufficed in quality for drinking. In this vein, although the objective of this study was not on examining the quality of rain water collected from rooftops, it is imperative to take into account that quality of collected water along with quantity should equally be given due concern. This is because both quantity and quality of water would affect the lives of households. On such conditions, this study suggests for a further research to look into the quality of collected rainwater. Such a research would require, among others, different methodologies taking technical aspects that measure water quality as critical.

Bibliography

Abdulla, F.A. and Al-Shareef, A.W., (2009), 'Roof Rainwater Harvesting Systems for Household Water Supply in Jordan' *Desalination*, Vol. 243, pp. 195–207.

Awuah, E., Nyarko, K.B. and Owusu, P.A, (2009), 'Water and Sanitation in Ghana' *Desalination*, Vol. 248, pp. 460–467.

Brilhante, O. and Frank, E., (2009), '*Municipal Environment Planning and Management Training*, IHS, Rotterdam.

Brilhante, O., (2010), 'Components Operation Maintenance and Integration with Plans: Core Group of Municipal Infrastructure and Services,' *Hand Out*, Session-3, SISUE, IHS, Rotterdam.

Blewitt, J., (2008), '*Globalisation and Sustainable Development, in Understanding Sustainable Development*', Earthscan, London.

Brook, P. J. and Irwin, T. C., (2003), '*Infrastructure for Poor People*', Washington DC, USA, The International Bank for Reconstruction and Development.

Cresswell, J. W., (2003), '*Research Design: Qualitative, Quantitative and Mixed Methods Approaches*', London, Sage Publications.

Cresswell, J. W. and Cresswell J.D., (2003), '*Mixed Method Research: Development, Debates, and Dilemma*', Available online at: http://www.google.com/search?q=Creswell+JW+2003+Research+Design+Qualitative+Quantitative+and+Mixed+Methods+Approaches+London+Sage+Publications&hl=en&tbs=bks:1&ei=kEAjTMOQOomPOLuq_ZMF&start=0&sa=N [accession date 2010, 18, June].

Ciuche, C., (2005), 'Integrated Urban Infrastructure in Romania: Case study Bucharest City', *Article*, IHS, Rotterdam.

Devas, N. and Korboe, D., (2000),'City Governance and Poverty: the case of Kumasi' *Environment & Urbanisation* Vol. 12(1), pp. 123–135, Available online at: http://www.bvsde.paho.org/bvsacd/cd26/enurb/v12n1/123.pdf [accession date 2010, 20, April].

De Vaus, D., (2001), '*Research Design in Social Research*', London, SAGE Publication Ltd., Available online at: http://books.google.com/books?hl=en&lr=&id=9yurQt7T65oC&oi=fnd&pg=PR13&dq=De+vaus,+D.+(2001).+Research+Design+in+Social+Research.+London,+SAGE+Publication+Ltd.&ots=nmVj-0sS9r&sig=O_jtHk9jssI6oev1oPtgzEwD9yY#v=onepage&q&f=false [accession date 2010, 17, June].

Evans, P. and Appleton, B., (1993), ‘Community Management Today: The Role of Communities in the Management of Improved Water Supply Systems’, Delft, The Netherlands, IRC, International Water and Sanitation Centre.

Fankhauser, S. andTepic S. (2007),’ Can Poor Consumers Pay for Energy and Water? An affordability analysis for transition countries’ *Energy Policy* 35 (2007) 1038–1049

Faulkner, A. and Albertson, M., (1986), ‘Tandem use of Hard and Soft Technology: an Evolving Model for Third World Village Development’, *International Journal of Applied Engineering Education*, Vol. 2, No. 2 pp 127-137.

Haldi, A., (2000), ‘A Participatory Approach to Sanitation: Experience of Bangladeshi NGOs’ *Health Policy and Planning 2000*’, Vol. 15 (3), pp. 332-337.

Handia,L., Tembo, J. and Mwiindwa, C., (2003), ‘Potential of Rainwater Harvesting in Urban Zambia’, *Phys. Chem. Earth* 28 (20–27), pp. 893–896.

Hasan, Q., (1995), ‘Sanitation: the First Choice for Progress of Nation’, *Wastan Special Issue* 1995.

Huysman, M., (2010), ‘Livable Slums,’ *Hand Out*, Session-2, SCCC, IHS, Rotterdam.

Kingsolver, B. (2010), ‘Fresh Water’, *National Geographic*, April 2010.

Kjellen, M. and Mcgranahan, G. (2006),*’Informal Water Vendors and the Urban Poor*’ International Institute for Environment and Development (IIED), London.

KPMG, (2008), ‘Kumasi, Ghana: Potential Opportunities for Investor’, Available online at:
http://www.fdi.net/documents/WorldBank/databases/ghana/kpmg_ghana.pdf.
[accession date 2010, 09 February].

Kumar,R., Singh, R. and Sharma, K., (2005), ’Water Resources of India’, *Curr. Sci*. 89 (5), pp. 794–811.

Lee, E.J. and Schwab, K.J., (2005), ’Deficiencies in Drinking Water Distribution Systems in Developing Countries’, *Journal of Water and Health*, Available online at:
http://www.jhsph.edu/water_health/_pdf/Lee_Schwab_JWH_3_2_p_109_2005.pdf.
[accession date 2010, 16 June].

Marais, GR., (1973), ‘*Sanitation and Low Cost Housing in Water Quality Management and Pollution Control Problems*, Oxford, Pergamon Press.

Martins, K and Sluiter, A., (1999), ‘*Private Sector Participation in the Water: a Study on the Water Supply in Kumasi, Ghana*’, MSc. Thesis, Universiteit Van Amsterdam, Amsterdam.

Motsi, K., Chuma, E. and Mukamuri, B., (2004), 'Rainwater Harvesting for Sustainable Agriculture in Communal Lands of Zimbabwe', *Phys. Chem. Earth* **29** (15–18), pp. 1069–1073.

Mugabi, J., Kayaga, S., and Nijru, C. (2006),'Strategic Marketing for Water Services in Deveoping countries' *Science Direct, Utilities Policy,* Vol. 15, No. (1), pp 1 - 8.

Ndezi, T.P., (2004), '*An Investigation of Strategic Partnership Approach for Providing Water Services to Informal Settlements: Findings from Sub-Saharan Africa*', PhD. Thesis, Loughborough University, Loughborough.

Njiru, C. (2003). *Improving water services: Utility-Small water enterprises partnerships.* 29th WEDC Conference, Abuja, Nigeria., Water, Engineering and Development Centre, University of Loughborough, UK. pp 263 - 266.

Njiru, C., (2005),' How Small Water Enterprises Can Contribute to MDGs for Water', Available online at: http://www.lboro.ac.uk/well/resources/fact-sheets/fact-sheets-htm/Small%20water%20enterprises.htm. [accession date 2010, 18 June].

Nyarko, K.B., Odai, S.N., and Fosuhene, K.B., (2006), 'Optimizing Social Inclusion in Urban Water Supply in Ghana', Available online at: http://www.switchurbanwater.eu/outputs/pdfs/CACC_PAP_Optimising_social_inclus ion _in_urban_water_supply.pdf. [accession date 2010, 02 March].

Nyarko, K.B., (2008), 'Private Sector Involvement in Drinking Water Supply in Ghana', *International Journal of Water*, Vol. 4, No. 3/4, pp. 197-215.

Plaza, A., (2009), '*Empirical Assessment of Adaptive Capacity of Low-Income Communities to the Impacts of Climate Change and Flooding: the Case Study of Ayigya in the City of Kumasi, Ghana'*, MSc. Thesis, IHS, Erasmus University, Rotterdam.

Rahardjo, B. and O'brien, D., (1994), 'Community Self-Financing of Water and Sanitation Systems', *Water Lines*, Vol. 12, No. (3), pp 10 -13.

Sarpong, K., and Abrampah, K., (2006),'Small Water Enterprises in Africa 4: Ghana' Available online at: http://www.wedc.iboro.ac.uk/knowledge/detail.php?book [accession date 2010, 16 January].

Taylor, P., (2007), 'Delivering the Twin-Track Approach through a Collaboration and Innovation, Available online at: http://www.water.org.uk/home/news/press-releases/innovation-forum-5-sept-07/innovation-web-5-sept-07.pdf. [accession date 2010, 16 June].

Thomas, T., (1998), 'Domestic Water Supply Using Rainwater Harvesting', Build. Res. Inform. **26** (2), pp. 94–101.

UN-HABITAT, (1989), '*The Conservation of Drinking-Water Supplies: Techniques for Low-Income Settlements*, Nairobi, United Nations Centre for Human Settlements.

UN-HABITAT, (2003), '*Water and Sanitation in the World's Cities*', Nairobi, United Nations Centre for Human Settlements.

UN-HABITAT, (2006), '*Meeting Development Goals in Small Urban Centres*', Nairobi, United Nations Centre for Human Settlements.

Vairavamoorthy, K., Gorantiwar, S.D and Pathirana,A., (2008), 'Managing Urban Water Supplies in Developing Countries: Climate Change and Water Scarcity Scenarios', *Physics and Chemistry of the Earth* , Vol. 33, pp. 330-339.

Van Dijk, M.P., (2006), 'Public-Private Partnership in Basic Service Delivery: Impact on the Poor, Example from the Water Sector in India', *International Journal of Water*, Vol. 4, No. 3/4, pp. 197-215.

Wedgewood, A. and Sansom, K., (2003), '*Willingness to Pay Surveys: a Streamlined Approach'*, WEDC, Loughborough University, UK.

White Paper on Basic Household Sanitation, (2001), available online at http://www.dwaf.gov.za/Documents/Policies/SanitationReviewPolicy.pdf [accession date ....]

WHO and UNICEF, (2000), 'Global Water and Sanitation Assessment 2000 Report', available online at http:/www.who.int/water_sanitation_health/global.htm. [accession date ....]

WHO and UNICEF, (2004), 'Meeting the MGD Drinking Water and Sanitation Target: the Urban and Rural Challenges of the Decade, Switzerland, World Health Organization.

Willoughby, K., (1990), *Technology Choice, a Critique of the Appropriate Technology Movement*, Intermediate Technology Publication, London.

World Bank, (1986), '*Information and Training for Low-Cost Water Supply and Sanitation: Rainwater Roof Catchment System*', Vol. 4.1, Washington DC., World Bank.

World Bank, (1986), '*Information and Training for Low-Cost Water Supply and Sanitation: Users Participation*', Vol. 2.4, Washington DC., World Bank.

World Bank, (1986), '*Information and Training for Low-Cost Water Supply and Sanitation: Health Aspects of Water Supply and Sanitation*', Vol. 3.1, Washington DC., World Bank.

World Bank, (1986), '*Information and Training for Low-Cost Water Supply and Sanitation: Sanitation Technology Selection*, Vol. 5.3, Washington DC., World Bank.

World Bank, (2001), '*Toolkits for Private Participation in Water and Sanitation*', Washington DC., World Bank.

World Bank, (2003), ‘Urban Services to the Poor: Thematic Group, available online at http://www.worldbank.org/urban/upgradinq/what.html. [accession date...]

Yin, R. K., (2003), ‘*Case Study Research: Design and Methods’*, London, Sage Publications.

Annex 1: Personal Questionnaires

Questionnaire for water (Rain Water Harvesting)
Ayigya, Kumasi, Ghana

Questionnaire number:…………/plot number……….
Name of the interviewer:

PART 1: To be filled in by interviewer

Name ……………………………………………Age……… Gender- Male/ Female
Name of the Community:..
How long have you been living in the community? :………..
House number:...
Years……….. Income………..
How long you have been living in this house?.......................

PART II: QUALITY OF HOUSING.

1) Material used for roof

Asbestos	Iron Sheets	Thatch	Tents/plastics	Other

2)Material used for walls

Brick	Concrete blocks	Mud Bricks	Pole and dagga	Iron Sheets	Other e.g. wood

3) Material used for rafters and purlins
a. Wood b. Bamboo c. Steel

4)Material used for floor
a. Concrete b. Earth c. Other (tiles)

5)Type of ownership
a. Rented b. Ownership

6)Number of rooms:……….

7) Size of the household……..

8)Number of rooms occupied if rented:……………..

9)Type of house:
a. Compound house single storied
b. Compound house multi storied
c. Single house- single storied
d. Single house- Multi storied

PART III: PERSONAL DATA

1) Marital status:

Single	Married/ living with spouse/partner	Divorced	Widow

2) Level of education

Illiterate	Read & write	Primary school completed	Secondary school completed	Professional education

3) Employment status

Housewife	Employed	Business	Unemployed	Main income earner (yes/no)

4) *Do you own the followings?*

a. Car b. Motor cycle c. Cycle d. Television e. Fridge
f. Radio g. Others

PART IV: IMPACT OF INFRASTRUCTURE

A) Source and quality of drinking water (Access to safe drinking water)

1)What is the source of drinking water of your household?

a. Individual connection from Ghana Water Company Limited
b. Standpipe (taps)
c. Borehole with hand pump
d. Shallow well
e. Natural source: river etc.
f. Buy from Vendors/neighbor seller

2)What is your opinion on the quality of the water that you use now?

a. Very good b. Good c. Average d. Bad e. Very bad

3)Do you treat the water?

Yes	No (if No, skip Q-4)

4)If yes, how do you treat the water?

Chlorination	Boiling	Other

B) Related to household income and expenditure

1)What amount do you pay for drinking water?

Amount/month (water bill in case you are connected with piped supply)	Amount you spend daily (in case, you buy from water vendor)			
	Less than 1 GHc	1-2.5 GHc	2.5-5 GHc	More than 5 GHc

2)What is your daily water consumption for your family?

1-5 gallons	5-10 gallons	10-15 gallons	15-20 gallons	others

C) Related to time with other household activities

Questions	Less than 30 min.	30-45 min	45- 60 min	1 to 2 hrs.	More than 2 hrs
1)How much time do you spend on fetching water?					
2)How much time do you spend on household tasks?					
3)How much time do you spend on income earning activities?					
4)How long do you have to wait for your turn at the water source?					

D) Related to health, condition household members

1) What is the general health condition of your family?

	Good	Average	Bad	Very bad
Yourself				
Your husband				
Your children				

2) How frequently do your children suffer from diarrhea?

a) Very frequently b) frequently c) hardly d) not at all e)I do not know

PART V: OPINION OF THE USERS ON AVAILABILITY, AFFORDABILITY, ACCESSIBILITY AND ACCEPTABILITY

A) Statements related to availability

Statement	I very much agree	I agree	I don't agree	I don't agree at all	I don't know
1) I have to buy water from vendors/neighbour seller.					
2)The water vendors/ neighbour seller charges comparatively high cost					
3)There is always mud and dirt in the water we buy from vendors					
4)I cannot always get water from water Vendors					
5) During the lean and scarcity seasons, water vendors charge higher cost					
6)The public water system or standpipe/ hand pump gets broken very often					
7)More people cannot make use of the standpipe/hand pump because of frequent break downs					

8)I collect rain water sometimes for my household use					
9)I have to fetch water from river/ponds during scarcity/water shortage period					
10)There used to be better piped water supply system before 2005					
11)The is always mud and dirt in the piped water					
12)There are a lot of leakages in the supply & distribution system of the piped water (GWCL)					
13)There is hardly any piped water distribution system in this neighborhood					
14)The is hardly any standpipe/hand pump in this area					

PART VI: OPINION OF THE RAIN WATER HARVESTING

1) Do you use rain water from rooftops?

a. Yes, for drinking
b. Yes, but not for drinking for washing, cleaning and bathing
e. No,
f. No, I do not have the collection facilities

2) What type of water storage facilities do you use?

a. In 20 liters gallons
b. 200 liters drums
c. PVC water tanks (Sintex, Poly tanks etc. having ……. liters capacity
d. self-constructed masonry/ RCC water tanks.
e. Others...................

3*) How often it rains here?*

a. Very rarely b. rarely c. frequently f. very frequently

4) Which months do the rainy season start and end in Kumasi?

a. Starts:.........
b. Ends:...........

6) Do you know any advantages of RWH? ***(can choose more than one options)***

a	It saves my expenditure on water	
b	I get more water	
c	I do not have to waste time in fetching water	
d	I do not know	

7)) Are you interested in having RWH system in your house?

a. Yes b. No

8) If yes to the above question, are you willing to invest in the installation of RWH system?

a. Yes, I would like to install
b. Yes, if I get some help from Government.
c. Yes, I would like to install but there is no suitable materials.
d. I am not sure; I need more information on RWH
e. No, I do not want the system.
f. your comments……………………………………………………………..

Comments/ observation of the researcher	**Any other detail information**

Annex 2: Price of Poly Tanks (water storage) in Ghana

OLY TANK (GH) LIMITED

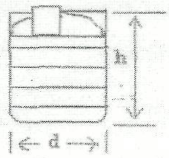
ATIONWIDE

Effective From 1st June 2010

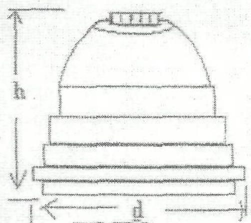
ia/Length (in Cms)	Height (in Cms)	Code	Model Name	Capacity (in Litres)	Capacity (in Gallons)	Price GH¢
ater Storage Tanks						
57	90	R 020	Rambo - 020	200	44	71
59	105	R 030	Rambo - 030	300	66	82
91	113	R 070	Rambo - 070	700	155	155
102	120	R 100	Rambo - 100	1,000	222	225
120	126	R 140	Rambo - 140	1,400	311	300
120	151	R 180	Rambo - 180	1,800	400	405
150	136	R 250	Rambo - 250	2,500	555	505
150	176	R 300	Rambo - 300	3,000	666	640
150	200	R 350	Rambo - 350	3,500	777	720
146	227	R 400	Rambo - 400	4,000	888	825
180	185	R 450	Rambo - 450	4,500	1000	900
185	200	R 500	Rambo - 500	5,000	1111	945
189	220	R 600	Rambo - 600	6,000	1333	1,065
201	233	R 700	Rambo - 700	7,000	1555	1,240
212	235	R 850	Rambo - 850	8,500	1888	1,400
218	250	R 1000	Rambo - 1000	10,000	2222	1,615
267	280	R 1500	Rambo - 1500	15,000	3333	2,425
281	323	R 2000	Rambo - 2000	20,000	4444	3,235
297	362	R 2500	Rambo - 2500	25,000	5555	4,400
318	412	R 3000	Rambo - 3000	30,000	6666	5,700
102	94	J - 60	Jumbo - 60	600	133	160
167	101	H100	Hippo - 100	1,000	222	300
176	127	H200	Hippo - 200	2,000	444	495
196	153	H280	Hippo - 280	2,800	622	700
aste Managem nt Products						
40	111	DB 34	Dust Bin - 34	340	76	120
68	109	DB24	Dust Bin - 24	240	53	106
65	91	DB12	Dust Bin - 12	120	27	93
31	32	DB 08	Dust Bin - 08	80	18	70
53	52	MP06	Multi Purpose Bin - 60	60	13	27
53	76	MP10	Multi Purpose Bin - 10	100	22	31
53	98	MP12	Multi Purpose Bin - 12	120	27	37
200	222	S.P.	Septic Tank			900
ther Products						
39	72	TC	Traffic Cone			34
185	230	PK	Poly Kiosk			920

ontact: Accra: P. O. Box 53"4, Accra North, Spintex .oad near Coca Cola
Behind Japan Motors, South Industrial Area,
Tel:(00233 21) 689824,689821,811576,814593 e-mail: pt@polygroupgh.com
Kumasi: P. O. Box 6379, Matress House, Near Central Market
Tel: (00233 51) 26822,26828, Fax 26823; e-mail soni@polygroupgh. Com

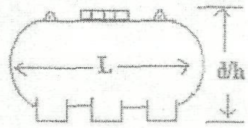
ote: All dimensions are the external dimensions to enable to provide space for installation.



RAMBO



JUMBO



HIPPO