


**ASSESSING EXISTING WATER DEMAND AND SUPPLY PATTERNS
AND REUSE OPTIONS AS ADDITIONAL SOURCES OF WATER IN THE
GREATER ACCRA METROPOLITAN AREA (GAMA)**

BY

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DECLARATION

I hereby declare that except for references cited which have been duly acknowledged, this work is the result of my own research undertaken under supervision towards the award of the Master of Philosophy degree in Geography and Resource Development, University of Ghana and that neither in whole nor in part has this work been presented anywhere for the award of another degree.

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DEDICATION

I dedicate this work to all those who have contributed immensely to the production of this thesis.



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LIST OF ACRONYNS

ATMA	Accra Tema Metropolitan Area
AVRL	Aqua Vitans Rand Limited
BLR	Binary Logistic Regression
DGRD	Department of Geography and Resource Development
BOD	Biological/Biochemical Oxygen Demand
BOO	Build, Operate Own Contracts
COD	Chemical Oxygen Demand
CWSA	Community Water and Sanitation Agency
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FC	Faecal Contamination
GAMA	Greater Accra Metropolitan Area
GEOR	Ghana Environment Outlook Report
GIS	Geographical Information System
GDHS	Ghana Demographic and Health Survey
GDP	Gross Domestic Product
GLSS	Ghana Living Standards Survey
GMET	Ghana Meteorological Agency
GoG	Government of Ghana
GPRS	Ghana Poverty Reduction Strategy
GSB	Ghana Standards Board
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Ltd
GWI	Global Water Intelligence

GWP	Global Water Partnership
GWSSA	Global Water Supply and Sanitation Assessment
(GWSC)	Ghana Water and Sewerage Corporation
HEP	Hydro-Electric Power
HDLCS	High Density Low Class Sector
HPZ	High Pressure Zone
ICWE	International Conference on Water and the Environment
IPCC	Inter-governmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
IWRM	Integrated Water Resource Management
KNUST	Kwame Nkrumah University of Science and Technology
KVIP	Kumasi Ventilated Improved Pit Latrines
LDHCS	Low Density High Class Sector
LPZ	Low Pressure Zone
MDG	Millennium Development Goal
MDMCS	Medium Density Middle Class Sector
MPZ	Medium Pressure Zone
MSTQA	Metrology, Standards, Testing and Quality Assurance
MWH	Ministry of Works and Housing
MWRWH	Ministry of Water Resources, Works and Housing
NACWA	National Association of Clean Water Agencies
NAO	North Atlantic Oscillation
NCWSP	National Community Water and Sanitation Programme
NEERI	National Environmental Engineering Research Institute
NGOs	Non-Governmental Organization
NRA	National Rivers Authority

NWP	National Water Policy
OECD	Organization for Economic Co-operation and Development
OGWRP	Old Goreangab Water Reclamation Plant
PHC	Population and Housing Census
PPP	Public Private Partnership
PURC	Public Utilities Regulatory Commission
RC	Reference Category
ROS	Reverse Osmosis System
SIP	Strategic Investment Plan
SPSS	Statistical Package for the Social Sciences
SWITCH	Sustainable Water Improves Tomorrow's Cities' Health
TMA	Tema Metropolitan Assembly
VRA	Volta River Authority
WHO	World Health Organization
WRC	Water Resources Commission,
WRI	Water Research Institute
WW	Waste Water
WWF	World Water Forum
WWTP	Waste Water Treatment Plants
UASB	Upflow Anaerobic Sludge Blanket
UNDP	United Nations Development Programme
UNSO	United Nations Sudano-Sahelian Office
USA	United States of America
WRM	Water Resources Management
WSRP	Water Sector Rehabilitation Project
WSSPS	Water and Sanitation Sector Programme Support

ABSTRACT

Attempts at addressing the increasing water shortage problems in the Greater Accra Metropolitan Area (GAMA) over the years have been biased towards supply management without critically assessing the efficiency of water use from existing schemes of demand management. This study sought to assess the current water demand and supply patterns, and how this affects wastewater reuse options. It investigated whether socio-economic status as well as status of household water supply in different income groups in the GAMA, specifically in East Legon, Dansoman Estates, Ashale Botwe and Teshie influenced wastewater reuse. Based on available data from Ghana Water Company Limited (GWCL), the demand for water in 2010 for GAMA was calculated to be 469,171.68m³/day with a corresponding supply through its current rationing programme as 404,841.00m³/day. There was therefore a considerable deficit of 64,330.68m³/day justifying analysis of coping mechanisms among residents.

Based on data collected using the mixed method mode of data collection, it is concluded that respondents resorted to various coping mechanisms such as rain harvesting, borehole water use, tanker and vendor services. Tanker service was most preferred by residents, because it was considered reliable even though expensive. Rain harvesting was considered cheapest but unreliable. Questionnaire responses among a total sample of purposely-selected 240 respondents in four study localities indicated 80% usage. Of the 20% who were not reusing, 73.2% were willing to reuse wastewater. It was further observed that the use of wastewater depend on income level and status of water supply. Further analysis of field data revealed that wastewater was a cheap source, more readily available and suitable for non-potable uses only. Nonetheless, wastewater reuse as a coping mechanism in the phase of increasing water demand by the rapidly increasing urban population in the GAMA should not be developed at the national level but at the individual and community levels with appropriate government support. The study concluded that if this potential demand management measure of wastewater reuse is properly advocated and implemented, Ghana would be in a good position to ultimately achieve her Millennium Goal 7 of ensuring environmental sustainability on time. The study strongly recommends that to address the problem in a holistic manner, all aspects of water demand, supply and coping mechanisms should be tackled to ultimately benefit all stakeholders.

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CHAPTER 1 BACKGROUND INTRODUCTION

1.1 Introduction

The issue of water permeates all aspects of life on Earth. Water is one of the most important necessity of life, without which there will be no existence on Earth. Access to safe water is therefore a fundamental human need and a basic human right (World Health Organization, 2000). Unfortunately, the available freshwater supplies are not evenly distributed in time and space (Gleick, 1993). Globally 1.1 billion people are without access to safe water supply and of this number, 27% is found on the African continent (GWSSA, 2000). It has also been predicted that by 2015, half of the world's population could be facing serious water shortages and could also run out of safe drinking water (Postel, 2002; Barker, 1997). It is therefore reasonable to deduce that one of the greatest challenges that the world would have to contend with in the coming decades is effective and sustainable water management to provide for the needs of the ever-increasing human population. Factors including growth in population, increased economic activity and improved standards of living leading to increased competition for, and conflicts over, the limited freshwater resource account for the increasing pressure on fresh water resources. This leads to the situation where a greater number of people lack access to adequate water supply for meeting their basic needs (Barker, 1997; Postel, 2002; IWRM, 2005).

According to IPCC (2008), the four main factors aggravating the water crisis the world over are population growth and high level of consumption where the world becomes more developed and the amount of domestic water used by each person rises significantly. The other factors relate to increased urbanization, which focuses on the demand for water among a more concentrated population, and significantly, climate change, which is shrinking freshwater resources.

As a result, a number of studies on water demand have been carried out in both developed and developing countries (Gleik, 2002; Savenije and Zaag, 2002; Lawton et. al. 2007; MacDonald,

2007; Lamptey, 2010). These studies are necessary to prepare for the unpredictability of water resources availability which is being experienced by many nations. The analysis of demand for water (non- potable and potable water), therefore, includes realistically forecasting future levels of demand which is an important and critical step in the economic analysis of water supply projects (MacDonald 2007; Lamptey, 2010). In recent times, the definition of water demand has switched from the amount required by the supply distribution to the amount of water required by the customer (Lamptey, 2010). The water resources required to satisfy consumer demand are substantially higher than the consumer demand itself. Leakage before and after water treatment is a key element. About 22% of water does not reach the end user because of leakage in the UK alone (MacDonald, 2007); and in Ghana, it is as high as about 50% (PURC, 2010). On a country basis, the demand for water per person is not even. For example, in the UK, Denmark, Spain, and Ghana, the demand is 150, 220, 289 and 140 litres per capita per day, respectively; representing varying needs in each country hence differing adaptation strategies.

Medalye *et al.* (2008) in a study in the USA, categorizes water according to its functions. These comprise physical, economic, social and political characteristics, of which a degree of government involvement is inevitable. These characteristics, though performing different roles are interlinked and therefore are dependent on each other. The first characteristic of water, physical, is its vital use as a resource for human and other animal and plant life (Gleick, 2002). Large water systems also provide regional and climatic weather services, whilst significant portions of water resources have become unusable due to industrial and agricultural pollution (Gleick, 2002). Medalye *et al.* (2008) further stresses that these inefficient and detrimental uses of water have led to concerns that its physical value is not reflected in its cost, which is an economic question.

In recognition of the physical problems stated above, the international development community clearly expressed the need for applying economic tools and principles to water use. The

International Conference on Water and Environment, held in Dublin, Ireland, in January 1992, concluded, among other things, that “water has an economic value in all its competing uses and should be recognized as an economic good” (the four Dublin principles) (ICWE, 1992). The commercial needs for water resources complicate matters, since it becomes difficult to measure and identify (Medalye *et al.* 2008). As such, it is difficult to subject water to market forces in a market economy. Furthermore, water has a long-term value to the sustainability of life and economic activity, over periods that dwarf those considered in conventional cost-benefit analysis. The value of usable water to future generations is hard to quantify and define and requires considerations of quantity, quality, timing, and accessibility.

With respect to the social dimension, it is argued that water is a social good in that the widespread availability of clean and affordable water improves both individual and social well-being. The public health impacts of inadequate water supply and sanitation has serious social and economic consequences for all. Being both a social good and a private good are not mutually exclusive conditions. In fact, more water for one individual can mean less water for other individuals who share a water-supply system. Classifying water as a basic human right introduces further social complications in terms of equitable distribution. Therefore, ensuring that the public receives an adequate supply of social goods requires some level of governmental action, since purely private markets often do not find it profitable to provide social goods (Gleick, 2002). What is more, decisions about water concern many interested parties or stakeholders. The decision to use more water in agriculture, for instance, could have implications for power generation, for municipal use, for industrial off take, and for the environment (FAO, 1995). Decisions over water could also entail major public health risks, such as the spread of malaria, cholera and diarrhoea hence, the need for national political decisions regarding water management.

According to the Ghana Environment Outlook Report (GEOR) (2006), freshwater covers nearly 5 percent (11,800km²) of the total land area. This is made up mainly of three major river systems. The Volta River System, which comprises rivers Oti, Sissili, White Volta and Black Volta, covers 70% of the total freshwater resources of the country. The South Western River System, such as Birrim, Ankobra, Pra, and Offin, takes 22% while the Coastal River System, which include rivers like Todzi and Aka, covers the remaining 8% (National Water Policy, (NWP) 2007; Ghana Environment Outlook Report (GEOR), 2006). Comparing Ghana's available freshwater resources with other countries like South Africa, Israel, Cyprus, and Australia that are considered as water scarcity nations (Global Water Intelligence, 2009), Ghana can conveniently be described as having abundant freshwater resources (NWP, 2007). However, estimates show that by 2015, Ghana, together with other nations in the sub-region would attain water stressed status (GEOR, 2006).

At the local level, in both the urban and rural areas, there are a number of people without access to potable water. The problem is closely related to inadequate supply, lack of maintenance resulting in broken hand pumps and silted dams as well as inability to pay for water because of lack of income-generating activities (GEOR, 2006). Significantly, population growth and concentration, rapid urbanization and industrialization resulting in increase in individual and collective needs have made water increasingly scarce and often of low or reduced quality (GEOR, 2006). In addition to these, current global climatic change processes are expected to affect both the spatial and temporal unpredictability of water availability in Ghana (Minia et. al 2004). The water resource base in Ghana, is therefore, under threat.

For most urban areas in Ghana, the provision of safe water services remains a critical challenge, not only for the realization of the Millennium Development Goals (Goal 7), which

seek to ensure environmental sustainability, but also for poverty reduction (MDG Report, 2006). According to the NWP (2007), the total demand for potable water in Ghana is ¹967,744 m³/day. The Ghana Water Company Limited (GWCL) supplies 605,469.69m³/day, amounting to 62 percent of total demand. Consequently, there are serious deficits in coverage. Significantly, the National Water Policy document (2007) notes that, of the estimated 50% of Ghana's population who reside in urban areas, 90% have access to improved drinking water sources. However, it is important to emphasize that, only about 30% of this have access to potable water, which, in most cases, is supplied intermittently. The other 60% depend on other protected sources such as standpipes, protected dug wells, protected springs and rainwater harvesting (NWP, 2007). While supplies have not kept pace with demand, the management of what is available has also come under public scrutiny. For instance, concerns have been raised with regard to the use of treated water for other purpose outside drinking and it is regrettable that in the face of these challenges, many people still water their lawns and wash cars with expensively treated water that other Ghanaians would queue to have access to (Water Focus, 2010).

Most areas within the Greater Accra Metropolitan Area (GAMA) lie outside the planned Ghana Water Company supply network. These areas include both poor informal settlements and rich developing areas (Songsore et al, 2009). Most inhabitants in these areas depend on informal water vending services, which is expensive and comes with a lot of risk factors such as contamination. To overcome some of these challenges and make water more accessible to people, various approaches have been advocated.

The National Water Policy of Ghana, for instance, provides a broad framework for the sustainable development of Ghana's water resources. It is targeted at all water users, water

¹ 1m³ is equivalent to approximately 1000litres

managers, investors, decision- makers and policy makers within the central governmental and decentralized structures, such as district assemblies, non- governmental organizations and international agencies. The policy also recognizes the various cross-sectoral issues related to water-use and the links to other relevant sectoral policies, such as those on sanitation, agriculture, transport, energy etc. The Ministry of Water Resources, Works and Housing is advocating among other things desalination, rainwater harvesting and more dependence on ground water resources as added options that could be explored to manage the current water crisis in urban Ghana.

However, another viable option that has never been considered in all these discussions is the case of wastewater reuse. Wastewater, constituting (grey and black water) refers to any water that has been used once. These include water used in the toilet, shower, bathtub, dishwasher, bathroom, kitchen sinks, and the laundry. Wastewater reuse has drawn increasing attention worldwide as an integral part of water resource management. Developed countries with scarce water resources like Germany, USA, Japan, Australia, Singapore, United Kingdom and South Africa, employ the use of wastewater. However, in developing countries, very few nations (like Zimbabwe, India and Namibia) employ this strategy to ameliorate their water problems. The majority of African countries do not employ its use or have very low use of the strategy for several reasons.

Currently, the Ghana National Water Policy does not consider wastewater reuse as an option for achieving sustainable water management. However, for some urban residents who are water stressed, increasingly, wastewater reuse is becoming part of their daily life. To what extent therefore, is this practice common in GAMA among different sections of the population with diverse water demand options? Consequently, this study seeks to assess the water demand patterns for selected residential communities in GAMA and the viability or otherwise of

adopting wastewater reuse as part of the sustainable water management at the household and communal level.

1.2 Problem Statement

Ghana is in a period of rapid urbanization. It is estimated that, 50.9 percent of the 24.7 million people live in urban areas (GSS, 2012), and about half of Ghana's 12.6 million urban residents live in the country's largest cities – Accra and Kumasi. Apart from natural increase, migration from rural areas to towns and cities is driving urban growth. In addition, the National Water Policy (2007) report predicted that if the growth rates of the 1990s persist, the urban population will reach 14 million by 2015, at which point more than half of Ghana's population will be living in towns and cities.

Unfortunately, the rate of urbanization outstrips current levels of urban water supply (National Water Policy, 2007). GWCL currently operates 82 urban systems, with an average daily output of $1,572,012 \text{ m}^3/\text{day}$ as against a daily demand of about $2,104,306 \text{ m}^3/\text{day}$ (NWP, 2007). Water is therefore rationed to many consumers, with only a few customers able to get 24-hour supply. In the peri-urban areas with new developments and the densely populated poor urban areas, customers receive supplies once a week, or not at all. This was reported by the Ghana Demographic and Housing Survey and the Ghana Living Standards Survey, Round 4 (GLSS4) where consumers had about 40% access to potable water and another 40% relied on neighbours and vendors, leaving the other 20% with no means of supply.

Additionally, the urban centres are the focus of Ghana's industrial and commercial activities many of which rely on inadequate and unreliable water supplies, which does not allow for

² 1 m^3 is equivalent to approximately 1000litres

efficient production. Most of the water supply systems were built over 30 years ago; hence the yields from supply sources is thus no longer able to meet current demand. In addition, the variability of rainfall has increased, and dry season shortages are becoming more pronounced. With rapid expansion of new housing developments, often ahead of utility services, more and more urban residents will depend on vendors and tanker services, at costs far in excess of utility rates. Mfalila (2000) contends that, for a long time, the traditional approach to water resource management has focused only on developing new supplies to augment available supplies in addressing increasing water demands. This has been the situation in Ghana and justifiably so, because of adequate supplies of raw surface water. Over the years, attempts made at addressing the increasing water shortage problems have been biased towards the supply side of the equation, without looking critically at the efficiency of water use from the existing schemes, that is, the demand side of the equation. This approach has serious consequence for sustainable water management, since it considers water as a non-finite commodity. This in turn leads to the overuse of the resource, overcapitalization, resource wastage and pollution.

Again, an important feature of this approach is that, it can neither explain nor suggest permanent and cost effective solution to the inadequate water supply. This is because the water supply management approach considers water needs as requirement that must be met and not as demands that are variable, changeable and subject to consumer behavior (Arlosoroff, 1998). Thus, sustainability is not likely to be achieved if the current trends persist, particularly with the wasteful use of water resources under the prevailing water management approach. There is the need for a paradigm shift in the approach to solving the water scarcity problems. Over the years, a number of options have been advocated but unfortunately, all these options points to the supply side; among them are desalination, rain water harvesting and shifting dependence from surface water to ground water resources.

Wastewater reuse has received attention worldwide as an integral part of sustainable water resources management. This move is driven by two major forces; scarcity of freshwater resources and heightened environmental concerns in terms of waste disposal options. In addition, economic considerations are also becoming increasingly important (Yang and Abbaspour, 2006). Esteben and Miguel (2008) further indicate that planned reuse of wastewater has been achieved in countries where water resources are insufficient and as a result of the need to increase water availability and to overcome the problem of wastewater discharges.

The issue of climate change has also been highlighted in several water related researches. Notable among them is one by NACWA (2009) whose scope is “confronting climate change by finding an early analysis of water and wastewater adaptation costs”. The study emphasizes that climate change is occurring at a greater rate and is affecting critical drinking water and wastewater services at an ever-increasing rate.

Ghana may not be classified as a country with insufficient water resources but it is also true that, a lot more people do not have access to potable water from centralized piped sources and depend on other sources that are so expensive and whose quality may also be compromised. For such people if there could be a way to reclaim and reuse wastewater at the individual and communal level, the country will be in a better position to deal with water shortages. To overcome the difficulties associated with access to water on a sustained basis, communities and households adopt a variety of options and one of them is wastewater reuse, which is gaining grounds in some households in newly developing areas in the city of Accra. Such water is used in car washing, toilet flushing, urban lawn watering, recreational amenities and others.

The critical questions are, under what conditions are groups of population adopting this practice? What use is the reused water put to and what kind of technology is involved? Again, to what

extent can this practice be encouraged as a viable option for sustainable urban water usage at the household and industrial level and even, urban agriculture in order to lessen the burden and cost of obtaining water for most users who are water stressed but require water for potable uses? Again, to what extent would different population groups affected differently by the current and future water situation embrace this practice?

Some gaps were identified from literature, which this study sought to fill. Most of the literature reviewed on water reuses related research focuses on reuse for irrigation purposes, and in developing countries (Pereirra, 2005; Mekala, 2008). Where reuse for industrial and residential sectors of the economy is the focus of study, it was usually in a developed country setting (Esteban and Miguel, 2006). Focus was centred on the advanced forms of reuse, while neglecting reuse at the traditional level. In addition, issues of perception were ignored, but rather emphasis was on the technical aspects of improving water quality (Yang and Appaspour, 2006). Admittedly, there was little documentation that exists on this practice in assessing the diverse uses of the reuse water, the cost benefits analysis of such an option, as well as the health implications and challenges associated with this practice.

Little is known about its sustainability especially advocating it as part of a sustainable water management strategy on a wide scale in Ghana. To ensure sustainable water resources management, it should be possible to develop a national policy to regulate this practice and if possible determine people's willingness to accept such a practice as a viable option for the increased water stress within the Greater Accra Metropolitan Area (GAMA). Consequently, this study seeks to examine the current demand and supply patterns with respect to water availability and accessibility within Greater Accra Metropolitan Area and how this affects water reuse options for different residential areas.

1.3 Literature Review

1.3.1 Introduction

Water is not only a limited resource but, the most strategically important resource on earth (Spivy, 2002). Water is essential for urban, industrial, and agricultural needs. With the ever-increasing urban population and economic activities, water usage and demand are continuously increasing. Hence, finding adequate water supply and fully utilizing wastewater become important issues in sustainable urban development (Lu and Leung, 2003). It is estimated that the consumption of fresh water by domestic usage accounts for up to 70–80% of the total volume of wastewater generated globally (Harrison, 1999; Asano, 2002). Considering the lack of adequate water availability to most urban areas in developing nations including Ghana, developing wastewater reclamation and reuse systems are of utmost importance to exploit new water resource and sustain natural fresh water supply. However, there is very limited experience in wastewater reuse in most developing nations.

This section of the study seeks to review literature on general water resources available globally with emphasis on Ghana, the changing supply and demand trends, in recent times, attributed to climate change, the state of wastewater reuse globally and the feasibility of developing new water resources, the cost-effectiveness of reclaiming wastewater and public attitude on wastewater reuse.

1.3.2 Global Water Stocks, Supply and Demand

Nearly 1.1 billion people, roughly 20% of the world's total population, lack access to clean drinking water (World Health Organization, 2000). About 97.5% of the total global water stocks are saline whereas 2.5% are the fresh water stocks. Of the fresh water stocks, the bulk, constituting 69.6%, is found in ice caps, glaciers, ground ice, permafrost and perennial snow

and 30.1% is the fresh ground water resource. Unfortunately, the remaining less than 1% of the world freshwater is what is readily accessible for direct human use which is found in lakes, rivers, wetlands, etc. (Eckstein & Eckstein, 2003).

This clearly shows that water is a critical renewable resource, imposing what can be a severe limit upon all major activities (Parker, 1998). The finite nature of water makes it difficult to find substitutes for it. Its depletion caused by wasteful uses may impose heavy economic costs not only on the present generation, but on the future generations as well (Pearce, 1994). The percentage of people served with some form of improved water supply rose from 79% (4.1 billion) in 1990 to 82% (4.9 billion) in 2000. At the beginning of 2000, one-sixth (1.1 billion people) of the world's population was without access to improved water supply and two-fifths (2.4 billion people) lacked access to improved sanitation. The majority of these people live in Asia and Africa, where two out of five Africans lack improved water supply (World Health Organization, 2000).

Looking at the MDGs (2010) report on achieving enough drinking water by 2015, the most progress was made in Eastern Asia, where access to drinking water improved by almost 30% over the period 1990 to 2008. In comparison to Africa, although the water coverage expanded in sub-Saharan Africa (22%) over the same period, it remains very low with only 60% of the population served. Further, the rural –urban gap, which is narrowing, is much wider when households having a piped drinking water on their premises are considered. In sub Saharan Africa, this percentage gap is 47% for rural areas versus 83% for urban areas (MDG, 2010). As a result, the water supply and sanitation sector will face enormous challenges over the coming decades in these two areas.

The Global Water Supply and Sanitation Assessment 2000 Report suggests that, to achieve the 2015 target in Africa, Asia, Latin America and the Caribbean alone, an additional 2.2 billion people will need access to sanitation and 1.5 billion will need access to water supply. By 2025, 3 billion people will need to be served with water supply and more than 4 billion with sanitation, globally. In effect, this means providing water supply services to 280 000 people and sanitation facilities to 384 000 people additionally every day for the next 15 years. Conversely, projected urban population growth, especially in Africa and Asia, suggests that urban services will face great challenges over the coming decades to meet fast-growing needs. At the same time, rural areas also face the daunting task of meeting the existing large service gap.

Mfalila (2000) observes that, in many countries today, water is being depleted at an alarming rate which far exceeds its regenerative capacity. The emerging trend shows overwhelming pressure put on water resources by the exponential growth in population which threatens its regenerative capacity. The suggestion is that, we are likely to reach the physical limits of water resources endowed upon us by nature, principally because of population growth and overconsumption which is directly proportional to demand and that this may lead to its depletion if the rate of its replenishment is lower than the rate of use (Daly, 1993; Turner, 1993; Kgathi, 1998; Lamptey, 2010).

Apart from population, other variables that determine water demand and put extreme pressure on available water stocks include the price of water, income levels, level of urbanization, and uneven rainfall distribution caused by climate change and climate variability. For instance, Furling (1996) insists that urbanization tends to increase the per capita consumption of water associated with the production of huge amount of waste and wastewater that threaten to deplete sources of water for human consumption. Lamptey (2010) also shares the same view. What is

more, with climate change, it has been predicted that increased temperatures might lead to a direct increase in the per capita consumption of water. Indirectly, this might reduce water supply due to increased evaporation and evapotranspiration and reduced groundwater recharge.

1.3.3 Climate Change Implications on Water Resources

Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems (Mall *et. al.*, 2006; Bates *et. al.* 2008). Observed warming over several decades is linked to changes in the large-scale hydrological cycle such as increasing atmospheric water vapour content, changing precipitation patterns, reduced snow cover and widespread melting of ice, and changes in soil moisture and runoff. Precipitation changes show substantial spatial and inter-decadal variability. Over the 20th Century, precipitation has mostly increased over land in high northern latitudes, while decreases have dominated from 10°S to 30°N since the 1970s (IPPC, 2008).

By the middle of the 21st Century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics. Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas. Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution, with possible negative impacts on ecosystems, human health, and water system reliability and operating costs (IPPC, 2008).

In the Intergovernmental Panel on Climate Change (2008) Report, there is high confidence that the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions, this benefit is likely to be counter-balanced by the negative effects of increased precipitation variability and seasonal runoff shifts in water supply, water quality and flood risks.

Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilization. Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defenses, drainage and irrigation systems as well as water management practices. Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems (Bates *et. al.* 2008).

Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies. Water resources management clearly affects many other policy areas, e.g., energy, health, food security and nature conservation. Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors (Bates *et. al.* 2008). Low-income countries and regions are likely to remain vulnerable over the medium term, with fewer options than high income countries for adapting to climate change. Therefore, adaptation strategies should be designed in the context of development, environment and health policies.

1.3.3.1 Climate Change Impact in Africa

About 25% of the contemporary African population experiences water stress, while 69% live under conditions of relative water abundance (Vorosmarty et al., 2005). However, this relative abundance does not take into account other factors, such as the extent to which water is potable and accessible, and the availability of sanitation (IPCC, 2008). Further, one-third of the people in Africa live in drought-prone areas and are vulnerable to the impacts of droughts, which have contributed to migration, cultural separation, population dislocation and the collapse of ancient cultures (World Water Forum, 2000). Droughts have mainly affected the Sahel, the Horn of Africa and southern Africa, particularly since the end of the 1960s, with severe impacts on food security and, ultimately, the occurrence of famine. The influence of the ENSO decadal variations has also been recognized in southwest Africa, influenced in part by the North Atlantic Oscillation (NAO) (Nicholson and Selato, 2000).

Concerning water reuse, wastewater transport and treatment technologies reduce or eliminate Green House Gas generation and emissions. In addition, wastewater management promotes water conservation by preventing pollution from untreated discharges to surface water, groundwater, soils, and coastal zones, thus reducing the volume of pollutants, and requiring a smaller volume of water to be treated (IPCC, 2008). Thus, treated wastewater according to IPCC, (2008) can either be reused or discharged, but reuse is the most desirable option for agricultural and horticultural irrigation, fish aquaculture, artificial recharge of aquifers, or industrial applications.

1.3.3.2 Climate Change Implications for Ghana's Water Resources

Recent report by Water Resources Commission, (WRI, 2010) is that, Ghana is vulnerable to climate change and variability by virtue of its location in the tropics. Its geographic location bordering the Atlantic Ocean to the south is exposed to contrasting oceanic influence and

atmospheric changes that can by far be receptive to extreme weather events (Dovie, 2009; EPA, 2009). Because of its small land surface, the whole country may be exposed to such changes and this can lead to important rainfall deficits, dry spells and drought variability, or rain sufficiency depending on the type of oceanic oscillation particularly the Inter-Tropical Convergence Zone (WRI, 2010).

Again, statistics reported by Dovie (2009), in WRI (2010) Report, show that severe drought, prolonged dry spells, variable rainfall regimes and rain floods of 1983, 1998, 2005 and 2007, respectively in Ghana are examples of extreme weather events due potentially to changes in climatic events. These events alter the quality of natural resources and generally impact on human security through water and food insecurity (WRI, 2010). The severe drought of 1982/83 caused the Government of Ghana (GoG) to apply for assistance to the United Nations Sudano-Sahelian Office (UNSO) to combat desertification (EPA, 2003). The implication was that parts of Ghana, particularly the semi-arid areas of the Northern parts and the South-East, qualified to be classified as desertification-prone and received assistance from UNSO to combat desertification. Minia et al., in 2004, predicted in a model that temperature would continue to rise and rainfall will decrease in all agro-ecological zones of Ghana. Likewise, a 10% change in precipitation or a 1°C rise in temperature can cause a reduction in water overflow of not less than 10%. Using scenarios, they also show that there will be reduction in water flows between 15-20% and 30-40% for the year 2020 and 2050 respectively (WRI 2000; Minia et al 2004; Owusu and Waylen 2009).

Significantly, the challenge of climate change and climate variability and impacts are heightened by enormous gaps in scientific and institutional capacity linking vulnerability to climate change and variability impacts, adaptation and mitigation (WRI 2010). However, the understanding of

how to cope with the potential impact of climate change on the water environment at regional, national and local levels are not well known due to very limited investigations (GWP-TEC 2007). The IPCC (2007) report therefore made it clear that, adaptation measures are necessary no matter the scale or consideration of mitigation measures.

1.3.4 State of Water Resources in Ghana

About 70% of raw water is abstracted from Weija Water Works, Kpong Water Works and Barekese Water Works located in the Greater Accra, Eastern and Ashanti Regions respectively. The rest comes from other Water Works like Owabi, Kwanyako, Dalon and Daboase Water Works. These raw water sources can be described chiefly in terms of coverage, physical and chemical properties (Pers. comm. GWCL, 2012). Of the three, Weija is the largest source, followed by Kpong and then Barekese. Below are characteristics explaining each.

Weija Waterworks is located 15 km west of Accra. The raw water is abstracted from the Densu River impounded by the Weija Dam with the Intake Tower just upstream on the Dam. From the Intake, the water is pumped to the Treatment Works via two Pumping Stations: The Old Weija Pumping Station (German) and the New Weija Pumping Station (Canadian). The Treatment Works are located at 800m from the dam, on a hill at an elevation of about 100 m (SIP/SYS.PLAN/GREATER ACCRA, 2011).

The raw water drawn from the storage reservoir at the existing intake can generally be characterized as follows. The water quality characteristics are varied and dependent on climatic conditions. It has little to average turbidity and of variable colour during the dry season. High chlorophyll A content is observed due to eutrophication of the reservoir. The algal concentration is very high from January through March, and is basically of the

cyanophyceae classification and the anabaena and microcystis genus. Metabolites of these algae (geosmin and methyl isoborneol-2) have been found in the water and are certainly the cause of the water's bad taste and foul odor observed during the critical algal bloom period. It has an average degree of hardness and is alkaline while its pH level is basic (alkaline). Dissolved oxygen is present throughout, including at the bottom of the reservoir (-6.70m). The water has been found to contain excessive quantities of manganese during certain periods of the year. Suspended solids in the raw water remain at a marginal level and no traces of pesticides were detected in the analyses completed. Currently, the Weija Water Works cannot be expanded to produce any more raw water beyond its present abstraction (OTUI, 1997).

Concerning Kpong Waterworks, raw water is drawn from the Volta River at a distance of 17km, approximately, downstream from the Akosombo storage dam. Since the construction of the dam in 1966, the quality of the raw water drawn has progressively improved and is now stabilized. The present characteristics of the raw water are as follows: firstly, the water has a low level of mineralization and is aggressive to calcium carbonate. It is also very slightly colored and almost free from suspended matter. Presence of nitrates, and trace amounts of iron and manganese are just barely detectable. It has a low concentration of organic matter (total organic carbon content in April 1996, in the samples taken by OTUI: 1.9mg/l) and low content of dissolved solids (< 20mg/l). Traces of hydrocarbons, plastifiers and steroids were detected in the analysis of the OTUI 1996 sample. The algae content remains low (200/ml), and cyanophyceae, possessing the potential to give the water a bad taste, represent only 40% of the algae present, i.e., 80/ml. This isolated measurement is confirmed during both the dry and rainy seasons (OTUI, 1997).

Risks related to the deterioration of Kpong water quality are tied to the present intensification of agriculture and consequent growth of agro-food industries in the Volta catchment basin. An increase in the water's pesticide content, enrichment of the aquatic milieu caused by soil erosion (bringing phosphorus from fertilizers with it), and the discharge of untreated effluent from agro-food plants are thus to be feared. This is a serious threat, and must be taken into account by the authorities to ensure that the quality of the raw water is maintained at its present level (OTUI, 1997).

Concerning Barekese Water Works, the only scope for expansion of the Kumasi water supply system is expansion of the Barekese Headworks, which consists of an impoundment storing the surface water flows of the Ofin River and its tributaries. The storage capacity of the impoundment is about 36 million cubic metres or equivalent to about 620 days of present day's capacity of the water supply system. At full development of the water treatment plant, the storage capacity will have an equivalent of 165 days storage of the planned ultimate water treatment capacity of ³218,400 m³/day (48MGD). It is therefore expected that there will be no difficulty in increasing the abstraction rate from the impoundment. The raw water drawn from the storage reservoir at the existing intake can generally be characterized as follows. The raw water originates from stored surface water, which is known to suffer from eutrofication. The result is bad odour, taste and colour problems in the water, which are difficult to treat. These bad odour, taste and colour problems are due mainly to the presence of organic compounds in the raw water. Some of the organic compounds can be removed by erosion (SIP, 2011).

³ 1m³ is equivalent to approximately 1000litres

1.3.5 Urban Water Supply in Ghana

A variety of water-service delivery models can be identified in Ghana. The different levels of services providing water include utility water supply services, private (intermediary and independent) water supply services and community managed water supply services. Households can rely on a mix of different service delivery models for their water supply. In Ghana, urban water supply is the sole responsibility of the Ghana Water Company Limited (GWCL) and Community Water and Sanitation Agency (CWSA) for rural communities. Accra, being an urban area is supplied by GWCL, which obtains its water source from the Densu River, and the Volta River by way of the Weija and the Kpong dams respectively (NWP, 2007).

In GAMA, although the utility, GWCL produces most of the water that is used, only about 51 percent of the population has direct access to utility water supply services (Adank et. al., 2011). The rest depend on private and community service providers, many of whom get their water from the GWCL system, either directly (through a connection to the network) or indirectly (e.g. through tanker services). A number of communities on the fringes of Accra are being served by systems independent from the utility system, including community-managed small town piped water supply systems implemented by the Community Water and Sanitation Agency (CWSA), and privately-operated and managed water supply kiosks, like the Water-Health Centres which can be found in the northwest of Accra (Adank et. al., 2011).

1.3.6 Rainwater Harvesting

Geerts, (2009) defines rainwater harvesting as the accumulation and storage of rainwater for reuse, before it reaches the aquifers. It is a source of drinking water, water for livestock, water for irrigation, as well as other typical uses given to water. According to him, rainwater collected

from the roofs of houses, tents and local institutions can make an important contribution to the availability of drinking water. In some cases, rainwater may be the only available or economical water source. Rainwater harvesting systems can be simple to construct from inexpensive local materials, and are potentially successful in most habitable locations.

In Ghana, rainfall decreases from the south-west of the country (2,000 mm/year) towards the north (950 mm/year) and the southeast (800 mm/year). With appropriate technology and incentives, rainwater harvesting could provide a reasonable amount of water for household and other institutional water needs thereby reducing demand on the pipe-borne system and therefore the resource. To harness this potential, the National Water Policy reports that, Government of Ghana will enact appropriate legislation to be implemented through authorities such as the Metropolitan, Municipal and District Assemblies, and also provide incentives towards making rainwater harvesting a viable option to supplement household and institutional water requirements (National Water Policy, 2007). Currently in Senegal and Guinea-Bissau, the houses of the Diola-people are frequently equipped with homebrew rainwater harvesters made from local, organic materials.

1.3.7 Wastewater Reuse

Wastewater recycling is one of the most emerging water sources today. Many people are not aware of the economic advantages that household wastewater recycling systems offer. Every time faucets are turned on and toilets are flushed, precious water that is not recycled is wasted. The term “wastewater” properly means any water that is no longer wanted, as no further benefits can be derived out of it. The Water Reuse Association defines reused, recycled or reclaimed water as water that is used more than one time before it passes back into the natural water cycle (General Electric, 2010). They include water from

bathroom showers, bathtubs, dishwashers, kitchen sinks, and laundry as well as outside faucets amounting to between 50 percent to 80 percent of residential wastewater.

Thus, water recycling is the reuse of treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, or replenishing a groundwater basin (referred to as groundwater recharge). Table 1.1 summarizes the suitability of different grades of water for use in different applications.

Table 1. 1: Suitability for Use of Different Grades of Water

Water Grade	Definition and Reuse Applications
Wastewater	Combined domestic effluent that contains sewage
Grey water	Water from a potable source that has already been used for bathing, washing, laundry or washing dishes
Reclaimed water	Water that has been treated so that its quality is suitable for particular specified purposes, e.g. irrigation, toilet flushing, etc.
Green water	Reclaimed water that has been treated to a relatively high standard, suitable for general use as a non-potable source in parallel with the potable source. It may be identified through inclusion of a green dye and supplied through a dedicated pipe work system
Drinking- water	Very high-quality water assured to be suitable for drinking by humans

Source: WHO, 2006a: 115

Biswas (2006) implied that in the coming decades, the major water problem that developing countries will face is not likely to be physical water scarcity, but continued deterioration of water quality.

Water reuse allows communities to become less dependent on groundwater and surface water sources and can decrease the diversion of water from sensitive ecosystems. Additionally, water reuse may reduce the nutrient loads from wastewater discharges into waterways, thereby reducing and preventing pollution. This "new" water source may also be used to replenish

overdrawn water sources and rejuvenate or reestablish those previously destroyed (General Electric, 2010). Several benefits of household wastewater recycling systems have been identified. From a broader and indirect perspective, there are many benefits and they include the following: less fresh water use; reduce strain on septic tanks; reduce strain on treatment plants; reclaim wasted nutrients; recharge groundwater; encourage plant growth and topsoil treatment economically; decreases the pollution sent to sensitive environments; watering yards and gardens; filtering septic systems; and irrigating fields.

Wastewater is produced in rural and urban areas, irrespective of whether it is used or not. For the last three decades, national governments have recognized the benefits of promoting wastewater reuse as a means of supplementing water resources and avoidance of environmental degradation. The value of wastewater is understood in arid and semi-arid countries and many countries are now looking forward to ways of improving and expanding wastewater reuse practices. Research scientists, aware of both benefits and hazards, are evaluating it as one of the options for future water demands (Vigneswaran and Sundaravadivel, 2004).

1.3.7.1 Global Perspective on Reuse

About 99 percent of wastewater is water, and only one percent is solid wastes. At present, existing unsatisfactory wastewater disposal practices can be observed in both rural and urban areas worldwide (Zhang, 2008), of which Ghana is no exception. In China, Chile and Mexico, extensive agricultural areas around urban centres are irrigated by wastewater (Xie et al.

1992; Sadik, and Barghouti 1994). The reuse of wastewater is also being experienced in the Arab region (Khouzam, 2003). Japan has several instances of grey water reuse in high-rise buildings through a dual reticulation system. In 1990, about 844 buildings in Japan were identified to have

wastewater recycling systems and the number keeps increasing through various economic incentives implemented by Government of Japan (Vigneswaran and Sundaravadivel, 2004). Further, there are many pilot scale dual reticulation schemes in Australia. Social surveys conducted in Melbourne indicated that people support recycling of bathroom and laundry wastewater. In Western Australia, domestic grey water reuse has been an accepted option for future urban expansions (Vigneswaran and Sundaravadivel, 2004).

In another instance, regular droughts in Namibia and a continuous shortage of potable water supply to its capital city Windhoek necessitated the city to investigate alternative sources of raw water. It was decided to exploit reclaimable water from the Gammams Water Care Works (Municipal Wastewater Treatment Plant) and the Goreangab Dam (Lahnsteiner et al, 2004). This led to the building of the Old Goreangab Water Reclamation Plant (OGWRP), which produced drinking water, utilizing the mentioned sources as raw water. This plant, after more than 30 years of successful operation, was in the second half of the nineties at the end of its viable life span. It was therefore decided to build a new, larger reclamation plant next to the old plant. According to the management of the plant and people of Namibia, the Windhoek experience was an unqualified success (Lahnsteiner et al, 2004).

There is potential for reuse at all system scales, from household level to the large irrigation schemes. Reuse has advantages as well as disadvantages at each level. The choice is conventionally a technical and an economic one, though some view it as important that, the community as a whole should become more involved in the working of reuse systems (Vigneswaran and Sundaravadivel, 2004).

Wastewater is the product of legitimate economic activities. Countries either invest in getting rid of it or suffer the environmental damage. Either practice has a pervasive impact on public health

and the sustainability of development. If wastewater is properly treated and reused, then it solves two problems, that is: saving local and, probably, regional environment; and ameliorating water deficit. For example, recycling reclaimed water and storm water for residential non-potable uses has been estimated to have potential to reduce residential water demands by an average of 40% to 50% in most Australian cities (Vigneswaran and Sundaravadivel, 2004).

1.3.7.2 Potential for Wastewater Reuse in Ghana

Sanitation service providers can be broadly grouped into three categories: municipal service providers, private service providers and self-supply (SWITCH, 2011). The municipal providers include septic emptiers, servicing both private WCs as well as public facilities. There are also private sector septic emptiers, servicing the same target group as the municipal septic emptiers. Finally, a number of people and institutions provide their own sanitation services. These include institutional sewer systems and on-site treatment sanitation facilities like pit latrines and KVIPs. Since rural water supply are mainly from non-potable or improved non-potable sources, the adoption of wastewater reuse might not be a feasible option for rural areas in Ghana. Again, since the bulk of water supply in urban areas in Ghana is from piped water sources but with inadequate and inconsistent flow, there is a huge potential for wastewater reuse. In Ghana, urban and rural sanitation infrastructure is poor. Only a small portion of the wastewater from the cities (mostly domestic) is collected for treatment. The bulk ends up in drains and nearby water bodies (Adu-Ahyiah and Anku, 2004). Conventional wastewater treatment plants are underutilized due to poor sewage network in the cities where they are located. Any significant improvement in the network will mean demolition of several structures to make way for network construction. In many other regional capitals, treatment facilities are few and even nonexistent in some towns. The rural areas have no means of treating the wastewater produced (Adu-Ahyiah and Anku,

2004). Small scale or decentralized systems of wastewater treatment is seen as an alternative to solving these problems both in the big cities and small villages in Ghana. Research by Adu-Ahyiah and Anku, (2004) showed that implementation of conventional wastewater collection, treatment and disposal systems is not economically viable as the financial and institutional resources, coupled with the efficiency required for their maintenance are beyond the means of most municipalities in Ghana. They, however, advocated that decentralized systems will be more sustainable than the conventional methods.

Potential for wastewater reuse in GAMA is feasible and very high. This is because, part of the infrastructure for such implementation have already been laid. An example is the UASB reactor at James Town. The major constraints, however is the lack of maintenance culture and technical expertise. Currently, the vast majority of the waste treatment plants are not working. The two central sewer systems are not operational and of the 35 institutional treatment plants, only four are functioning. Most wastewater is disposed off in soak-away or storm drains and by throwing it into the street or compound. Part of this water infiltrates and joins the groundwater resources and part flows to the sea through the storm drainage system. Most of this flows untreated into the ocean.

A few years ago, a large modern biological treatment plant started operation at Accra's Korle Lagoon, but it handled only about 8% of Accra's inner-city wastewater from domestic and industrial sources. The system had a capacity three times greater than it used, but was constrained by the small urban sewerage network. Only about 10% of the Accra's wastewater was collected for some kind of treatment (Huibers *et al*, 2003). EPA, through its enforceable regulations is attempting to reverse the trend especially in commercial and industrial settings so that wastewater that is treated before release into the environment will now be reused for other non-potable purposes, making potential for reuse a reality.

The three sectors of the economy where potential for reuse is very high are domestic, agriculture, and industrial (WHO, 2006). For example, in urban areas of Victoria, the sewerage system is the preferred way to handle household wastewater, including grey water. If households in sewerred areas are interested in utilizing grey water on their own property, they usually install an approved system to collect and treat grey water. However, in areas that are not sewerred, households rely on individual wastewater treatment systems. These households are however mandated to adopt the risk management measures set by EPA (EPA-Victoria, 2008).

Industrial reuse of reclaimed wastewater represents major reuse next to irrigation in both developed and developing countries. Reclaimed wastewater is ideal for many industrial purposes, which do not require water of high quality. Industrial wastewater in Ghana is generated from breweries, textile, chemical, pharmaceutical and mining industries. Most of these industries empty their wastewater into nearby drains without treatment even though they could be exploited positively (Ghana Environment Outlook Report, 2006). Often these industries are located near populated areas where centralized treatment facilities already generate reclaimed water. Depending on the type of industry, reclaimed water can be utilized for cooling, processing, etc. (Vigneswaran and Sundaravadivel, 2004). Pilot scale feasibility studies carried out in Australia by the above authors have concluded that it is possible to economically treat the domestic wastewater to achieve adequate quality for reuse as cooling water.

Wastewater use for irrigation generates livelihoods for farmers, agricultural labourers, produce transporters, market brokers and produce vendors. Consumers also benefit by obtaining access to fresh and cheap produce. Hence, Okun (2000) and others have concluded that the wastewater use in irrigated agriculture is essential to cope with water scarcity (Okun, 2000; Hamdy, 2001; Pereira *et. al.* 2002 and Hamdy, 2004). According to Vigneswaran and Sundaravadivel (2004),

agricultural irrigation has, by far, been the largest reported uses of wastewater. About 41% of recycled water in Japan, 60% in California, USA, and 15% in Tunisia are used for this purpose. In developing countries, application on land has always been the predominant means of disposing municipal wastewater as well as meeting irrigation needs.

Several advantages may be related to such use. These include adding to limited available water supplies, decreasing pollution of rivers and other water bodies, conserving high quality water for more stringent water uses, conserving nutrients in wastewaters, so decreasing the amount of fertilizers use and increasing crop yield. However, the use of wastewater in irrigation involves risks and negative impacts of great importance (Pereira, 2005). Negative aspects have to be controlled, hopefully eliminated through wastewater treatment and management to make it safe wastewater reuse and really gain the related advantages (Pereira *et. al.* 2002; Choukr-Allah and Hamdy, 2004).

Vigneswaran and Sundaravadivel, (2004) again identified potential application of reclaimed wastewater for landscape irrigation. These include use in public parks, golf courses, urban green belts, freeway medians, and residential lawns. This type of application is one of the most common applications of wastewater reuse worldwide, which can be conveniently adopted in Ghana.

1.3.8 Issues Influencing Reuse

The use of wastewater for a variety of purposes is gaining increased popularity as a means of preserving scarce freshwater resources in the three main sectors of the economy, domestic, agriculture, and industry (WHO, 2006). Thus, the potential applications for wastewater reclamation worldwide include urban agriculture, industrial reuse, non-potable urban use and

the most challenging target, portable reuse. Lu et.al (2003) however note that, notwithstanding the use, wastewater reclamation and reuse planning require the support of the whole society including public recognition, financial aid, and legislation through government. Hence, whether wastewater reuse is appropriate or not depends upon careful economic considerations, potential uses for reclaimed water, stringency of wastewater requirement and public policy wherein the desire to conserve rather than develop available resources may override economic and public health considerations (Lu et.al., 2003). This notwithstanding, issues of health cannot be ignored where the presence of pathogens and chemicals in wastewater poses potential risks of human exposure during potable or non-potable water reuse processes, which may undermine the benefits obtained with more efficient utilization of water resources.

In all this, wastewater systems operate under two systems, centralized or decentralized. A decentralized system, which is often preferred as an alternative, may be defined as the collection, treatment, and disposal or reuse of wastewater from individual homes, clusters of homes, isolated communities, industries or industrial facilities, as well as from portions of existing communities at or near the point of waste generation (Crites and Tchobanoglous, 1998). The reasons are that, decentralized wastewater treatment plants are easy to manage, cost effective and have high public acceptance than centralized wastewater treatment plants.

1.4 Conceptual Framework

A common characteristic of water demand in urban areas worldwide is its relentless rise over many years, and projections of continuous growth over coming decades. Water demand is very complex and can be explained by multiple indicators (Butler and Fayyaz, 2006). Mfaila (2000) indicates that, among the variables that hinder the achievement of sustainability of water as a resource by its influence on the demand for water, is population increase. Kgathi, (1998), also

notes that, population is directly proportional to the demand for a resource and this may lead to its depletion if the rate of its replenishment is lower than the rate of use. Aside population growth, other variables that influence water demand include the price of water, income levels, level of urbanization, industrial growth characterized by a shift to urban areas and rising standard of living associated with changes in lifestyle, uneven rainfall distribution, and possible effect of climate change. With regards to climate change, Butler and Fayyaz, (2006), have observed that, its detailed implications are not yet clear, and depend on global location. This must at least increase the uncertainty in security of supply.

As the economy grows, people's income increase and in turn lead to changes in lifestyle. This is often accompanied by increased per capita water consumption. This changing living standard will have a definite influence on the demand for water particularly domestic water as people's possession of water intensive appliances like washing machines and dishwashers increases. This uncontrolled usage of water is most apparent within the higher income households, which is also extended to significant outdoor usage in watering gardens, filling swimming pools and washing cars.

Mfalila (2000) also contends that, the other dimension of the problem to scarce water resources is the user perspective. According to him, societies regard water as a near-free commodity that will forever be available. This reflects in their nonpayment culture, which is among the topmost common reasons that accounts for the wasteful and unsustainable use of water. Most economists have linked this to the failure of the configuration of markets which have left the resource outside the domain of market forces (Turner et al, 1994: Winpenny, 1997).

For most developing countries that have significant proportions of their urban populations without access to piped connected portable water, water resources management has been focused on the traditional approach of developing new supplies to support available supplies in solving increasing water demands. Again, as observed by Butler and Fayyaz (2006): xiii;

“Meeting the increasing demand from existing resources is self-evidently an uphill struggle, particularly in water stressed or water scarce regions, in the developed and developing world alike. There are typically two potential responses; either ‘supply-side’, meeting demand with new resources or ‘demand side’, managing consumptive demand itself to postpone or avoid the need to develop new resources”.

Nevertheless, for most developing nations like Ghana, the supply side has been the option. However, worldwide, there is considerable pressure from the general public, regulatory agencies, and some governments to minimize the impacts of new supply projects (e.g. building new reservoirs), implying that the emphasis should be shifted towards managing water demand by best utilizing the water that is already available (demand management). Water demand management is therefore the alternative to increased water supply to meet growing demand (Mfalila, 2000).

Water demand management involves the adoption of policies or investment by a water utility to achieve efficient water use by all members of the community. According to Butler, and Fayyaz (2006), a demand management plan may involve a wide range of demand management measures including water conservation, pricing, education and legal measures (Figure 1.1).

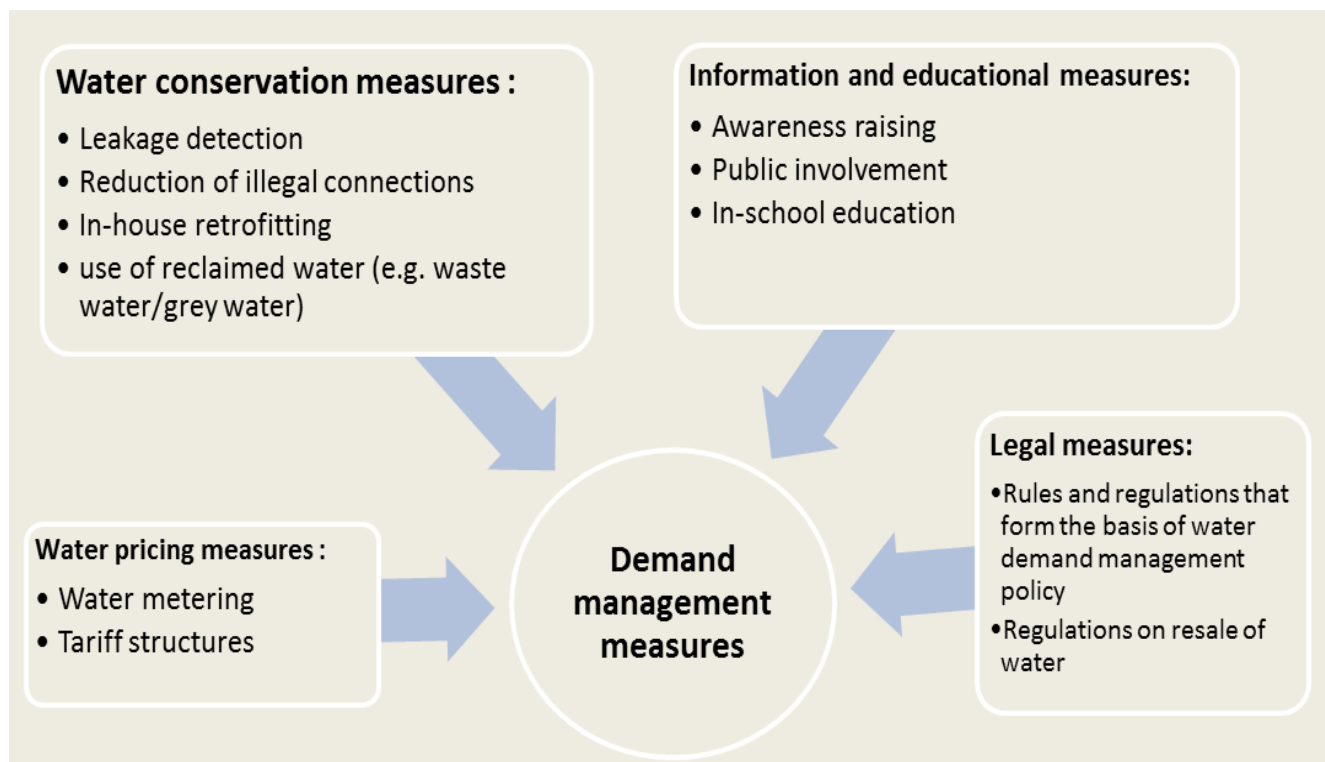


Figure 1. 1: Framework of Water Demand Management Measures

Source: Butler and Fayyaz (2006)

A comprehensive framework for understanding water management is described below. The framework was developed through research on water demand management for New Zealand and overseas in particular relation to policy required to promote uptake. It was supplemented with information gathered through a series of demand management council workshops where council staff considered what demand management approaches best suited their particular locality and situation. According to them, the framework is not prescriptive but offers a range of approaches that can be adapted to the specific context of each city or district. The framework identifies and provides three key elements or pathways to develop a demand management plan to meet required outcomes. The elements include management context, options and policy considerations (Lawton et. al., 2008).

The management context is viewed at the global, national, regional and local level. Each level has its unique influence on water management. So according to the framework, while a demand management plan will clearly reflect the local context; considerations at the higher levels are increasingly driving local policy. So given the long lifetime of water infrastructure it is worth anticipating how external forces will influence regional and local conditions (Lawton et. al., 2008).

The management option is in two modes; they are *key considerations* and *how to achieve them*. These considerations are seen in the form of effective cost, building resilience, satisfaction and overall goal of sustainability. How to achieve these is in the form of maintenance culture, water efficient technologies like grey water reuse which this research is advocating and other related methods. At the policy level, the framework considers more lateral thinking, time and financial resources. This may be achieved through non-regulatory policy or they might require a legislative route to make them mandatory. Management of grey water emerges as a key consideration in the demand management options category and for the study.

Several models have emerged for addressing wastewater reuse. They include studies by Mfalila (2000) on Water Demand Management in Greater Hermanus in South Africa; Lu and Leung (2003) on potential of developing shower/laundry wastewater reclamation and reuse system in China; and Yang and Abbaspour, (2006) on analysis of wastewater reuse potential in Beijing. Other models by Kaercher et al. (2003) and Kularatne et al. (2005) also focused on pricing of grey-water reuse. Marks et al. (2002) in Sydney also reported that many studies on public perception and acceptance of recycled water were done in the past as pioneered by Bruvold in 1970, 1972 and 1988. In recent times, he reported that a fewer number of studies have compared perceptions about recycled water. They include Dolnicar and Shafer 2006, 2007, and 2009;

Dolnicar and Hurlimann 2010. The above models have varied strengths and weaknesses. Whilst some focus on the technical aspects only, others consider issues at the economic, perception or policy level only. In addition, the general conclusions drawn from each of these studies also vary across locations and dates of measurement.

This thesis recognizing the shortcomings of existing models, adopts an integration of a number of frameworks, which together seek to give a comprehensive demand management measure integrating economic, social, health, political and technical issues in an urban setting.

The adapted framework ‘‘Water supply and Demand Management (Reuse) Framework’’ (Figure 1.2) identifies two key components, water supply and demand from various sources. Closely related is the second component, demand management measures comprising conservation, pricing, education and legal measures. Whilst each of these measures impact directly on wastewater reuse (as shown by the arrows), they also affect each other reversibly to help optimize reuse methods. For example, water conservation means efficient use of a resource. This resource must undergo a certain pricing regime to make it attractive and acceptable to its intended audience. To make this work, there must be adequate education on the use of the product to break all public perceptible barriers and finally legal measures, which will enable reuse methods to be incorporated into the national policies on sustainability (Figure 1.2).

Of the four measures, water conservation, with emphasis on wastewater reuse emerges in several literatures at the global, regional and local debate as the surest way forward to addressing water problems. The most basic justification is that, beside the direct benefits of increasing water supply, it saves the environment from the damaging effect of dumping wastewater and supports sustainable development (Gardner- Outlaw and Engleman 1997; Khouzam, 2003).

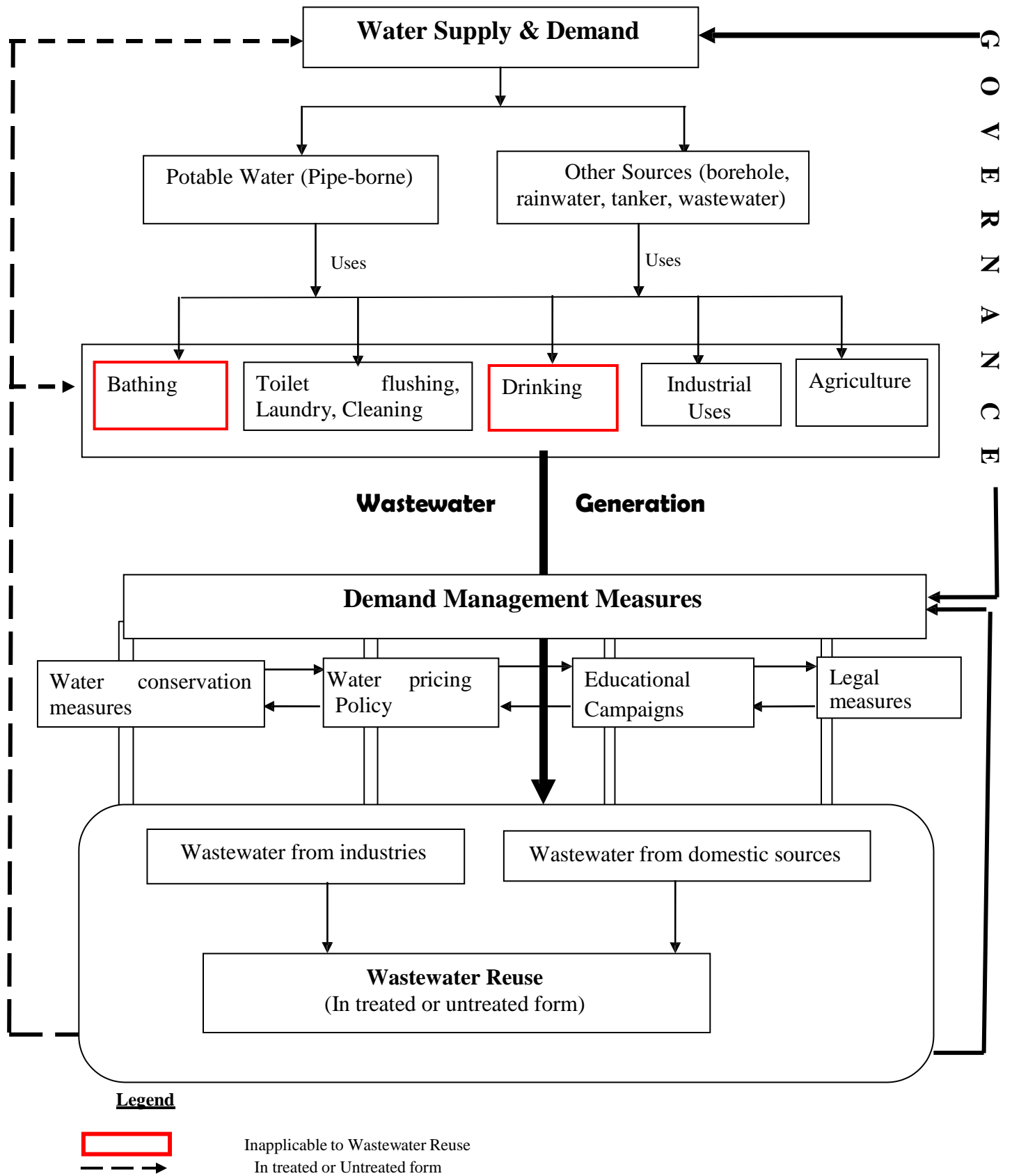


Figure 1. 2: Water Supply and Demand Management (Reuse) Framework

Source: Adapted Framework/ Fieldwork 2011

However, the option of wastewater reuse as the acceptable form of conservation is grey water. Grey water is water from a potable source that has already been used for bathing, washing, laundry or washing dishes and does not contain sewage. The goal of water demand management for grey water option is sustainability in the era of escalating population growth in urban areas like GAMA. This model seeks to explain not just the debate of water management but provides an empirical framework for understanding water demand management measures in the GAMA which this thesis seeks to achieve.

As can be seen in the Figure 1.3, a major part of the potable water stream is used in bathhouses, showers, hand washing basins, laundry machines, kitchen sinks, and industries forming grey water. Grey water in general, has a low content of organic matter and pollutants. The rest of the potable water stream is used to flush toilets forming the black water. The two, grey and black water form wastewater.

Wastewater can be reused without any treatment. Alternatively, it can be discharged from households into local decentralized Waste Water Treatment Plants (WWTP) (Yang and Abbaspour, 2006) or natural treatment systems like waste stabilization ponds (Awuah, 2007). In some cases, centralized wastewater reclamation systems are utilized (Adu-Ahyiah and Anku, 2004). However, centralized wastewater treatment plants have been found to be expensive to operate (Yang & Abbaspour, 2006). An example in Ghana is the UASB reactor at James Town, which was operating at 10% capacity.

Reclaimed water can be used for many non-consumptive purposes like urban lawn watering, washing cars and flushing toilets. From Figure 1.3, the uses to which the wastewater can be put to, traces back to the uses of water but exclude uses like drinking, cooking and bathing due to

health reasons. Further, the extent to which these reuse options becomes operational depends on other factors like the acceptance or otherwise from people (perception), the kinds of technologies involved, the health implications and the cost benefit analysis of such enterprises. Finally, equally important to any water demand management approach like wastewater reuse is the issue of governance, which is central to the sustainability of the environment (Lawton et al., 2008). Governance provides the legal and institutional framework, funding arrangements, and education needed for successful acceptance of such policy. Carden *et. al.* (2009): p3, assert that

“the overarching institutional impediments to sustainable urban water management are the lack of coordination of governing policies and regulations, fragmented administrative frameworks and the limited attention to institutional learning. They also note that; many of the barriers inhibiting the adoption in the city are social and institutional rather than technical, while a range of technologies may be available, human behavior and matters of governance remain major challenges in the implementation of such technologies”.

1.5 Objectives

The general objective of this research is to:

Assess existing water demand, supply patterns, and reuse options as additional sources of water in Greater Accra Metropolitan Area (GAMA).

The specific objectives are to:

- i. Assess potable water demand and supply patterns at the household and municipal level in GAMA. This objective is to give a preview and then analyze the water situation in the study area before considerations of where wastewater reuse will be most feasible if it can be exploited.
- ii. Identify existing informal arrangements households undertake to cope with water stresses. This objective is based on the assumptions that households who resort to

various coping mechanisms may be influenced by local conditions in the various urban and rural environments. Hence the need to identify these unique circumstances that influence their various choices of adaptation

- iii. Explore the extent to which wastewater is being used informally in households and industries. This objective brings to bear the Ghanaian use of wastewater in forms not investigated by most researches. The use of advanced and informal methods will be explored to bring a balance in the adoption of concept, so that all categories of stakeholders will be covered in its adoption
- iv. Assess the perception of stakeholders on the economic, social and health implications of wastewater reuse. This objective exploits all the factors that can impinge negatively or positively on reuse

1.6 Hypotheses and Proposition

1.6a Proposition

- i. Demand for water is dependent on socio-economic status of respondents

1.6b Hypotheses

- i. Ho The type of water coping mechanism is not dependent on status of household water supply
- ii. Ho Wastewater reuse is not dependent on level of education of respondents in the communities
- iii. Ho Wastewater reuse is not dependent on the status of household water supply

1.7 Rationale of Study

At the policy level, there is a raging debate on the quantity and quality of available potable water to several communities in Ghana (National Water Policy, 2007). Even though the Ghana Water Company Limited (GWCL) is obligated to make potable water available and accessible, for domestic and industrial consumption, there is still a shortfall of about 50% of Accra's water demand (National Water Policy, 2007). Most consumers are therefore compelled to adopt multiple alternatives for getting access to potable water (Water Focus 2010). Among them are the sinking of boreholes and rainwater harvesting. However, the increasing concern of ground water contamination and the unreliable rainfall pattern especially in Accra as well as the possible impacts of climate change may render these options unsustainable (National Water Policy, 2007).

A viable alternative to addressing the critical water availability issue at the household and municipal level is the development of traditional water reuse systems which are relatively cheaper especially if implemented at the decentralized level. This option is being implemented as part of water conservation practices in some households and industries. While attempts are being made to increase infrastructure by GWCL to address the water problem, these are often very expensive. It is therefore important to critically understand the prevailing water supply systems and reuse patterns as additional sources of water for urban households with severe water stresses. This is acute in most newly developing communities and poor urban households without access to treated water.

There is therefore the need to bridge observed information gap created between consumers and providers of water with the view to providing solutions to solve the crisis. The information gap on the water crisis warrants the need for this research.

1.8 Organization of Study

The study is organized into eight chapters. Chapter one is the general introduction of the research work and emphasizes on the problem governing the research. It also discusses the conceptual framework on which the research is based, study objectives, hypotheses and rationale of the study. Another important aspect of this chapter is the literature review, which discusses water issues and wastewater reuse in a global, regional and local context focusing on best practices and challenges. Chapter two focuses on research design and study methods including how data are analyzed and interpreted. Emphasis is also placed on research scope and design highlighting sampling procedures for primary stakeholders, focus group discussions and in-depth interviews. Types and sources of data are also discussed.

Chapter three is based on the physical, demographic and socio-economic profile of GAMA. This chapter focuses on the general characteristics of the study area that have a direct influence on water availability. Some of the specific issues discussed include climate change indicators of the area, drainage basins, economic role of water and how this affects GDP, policy issues, and ultimately human induced activities on water resources.

Chapter four provides an overview of the current demand and supply patterns with respect to water availability and accessibility within GAMA and how this affects water reuse options for different residential areas. Chapter five focuses on the coping mechanisms households undertake to cope with water stresses. These include rainwater harvesting, borehole water, wastewater reuse, tanker and vendor service.

Chapter 6 focuses on wastewater reuse as a coping measure at the household levels, exploiting the various sources, knowledge and determinants of reuse. Chapter 7, still focusing on wastewater reuse, exploits the perception and acceptability of reuse methods. Attention is placed on socio-cultural

factors, cost implications and public health concerns of reuse methods. Also discussed are centralized and de-centralized treatment systems, and very importantly the role of governance.

The final chapter, 8, provides a summary, conclusion and recommendations for policy and future research.

CHAPTER 2 RESEARCH METHODS

2.1 Introduction

This chapter focuses on the field methods used to carry out the research in the Greater Accra Metropolitan Area (GAMA). The design of a research, which is key to any research, focuses on the logical manner in which research is carried out. A good design ensures that evidence collected enables one to answer questions or to test theories as unambiguously as possible. The data collection techniques employed includes both qualitative and quantitative methods. The scope of the study focused on households and other water related stakeholders. A reconnaissance survey was first undertaken two weeks prior the actual fieldwork which commenced in July, 2011, primarily to choose study areas and for the researcher to assess the water situation in the localities for the study and to assess the general perception of the target population on the subject matter. It aided in the choice of sampling technique, instruments and questionnaire design used for the purposes of data collection.

2.2 Research Design and Selection of Study Communities

Primary data were generated from semi-structured questionnaires through a survey of the selected population to give an empirical validity to the findings. The selection of study communities for the primary stakeholders was made up of household heads. A stratified sampling technique was employed to obtain a sample size of 240, for Ashale Botwe, East Legon, Teshie and Dansoman Estates using the 2000 Population and Housing Census Survey Report as a guide (Figure 2.1; Table 2.1).

Stratification was based on income classes, water availability and population density. Research done by Songsore *et. al.*, (2008) showed that, Teshie community is an indigenous High Density Low Class Sector (HDLCS) and has a local economy characterized by low skills and

unemployment among the youth. Majority of the residents have low income and are involved mostly in informal production. Teshie also has poor access to water, which is mainly through communal standpipes and vendor services (Songsore et. al., 2008). The reverse can be said of East Legon, a Low Density High Class Sector (LDHCS) with access to rationed and good potable water supply. Conversely, Ashale Botwe combines both Medium Density Middle Class Sector and Low Density Middle Class Sector with access to water through vendor services only. Dansoman Estates is a Medium Density Middle Class Sector (MDMCS) with access to adequate water supply. In addition, qualitative responses were sought through interviews, which were held with some managers of urban water in GAMA and some opinion leaders. Finally, one focus group discussion each was organized in each of the four localities for the household surveys.

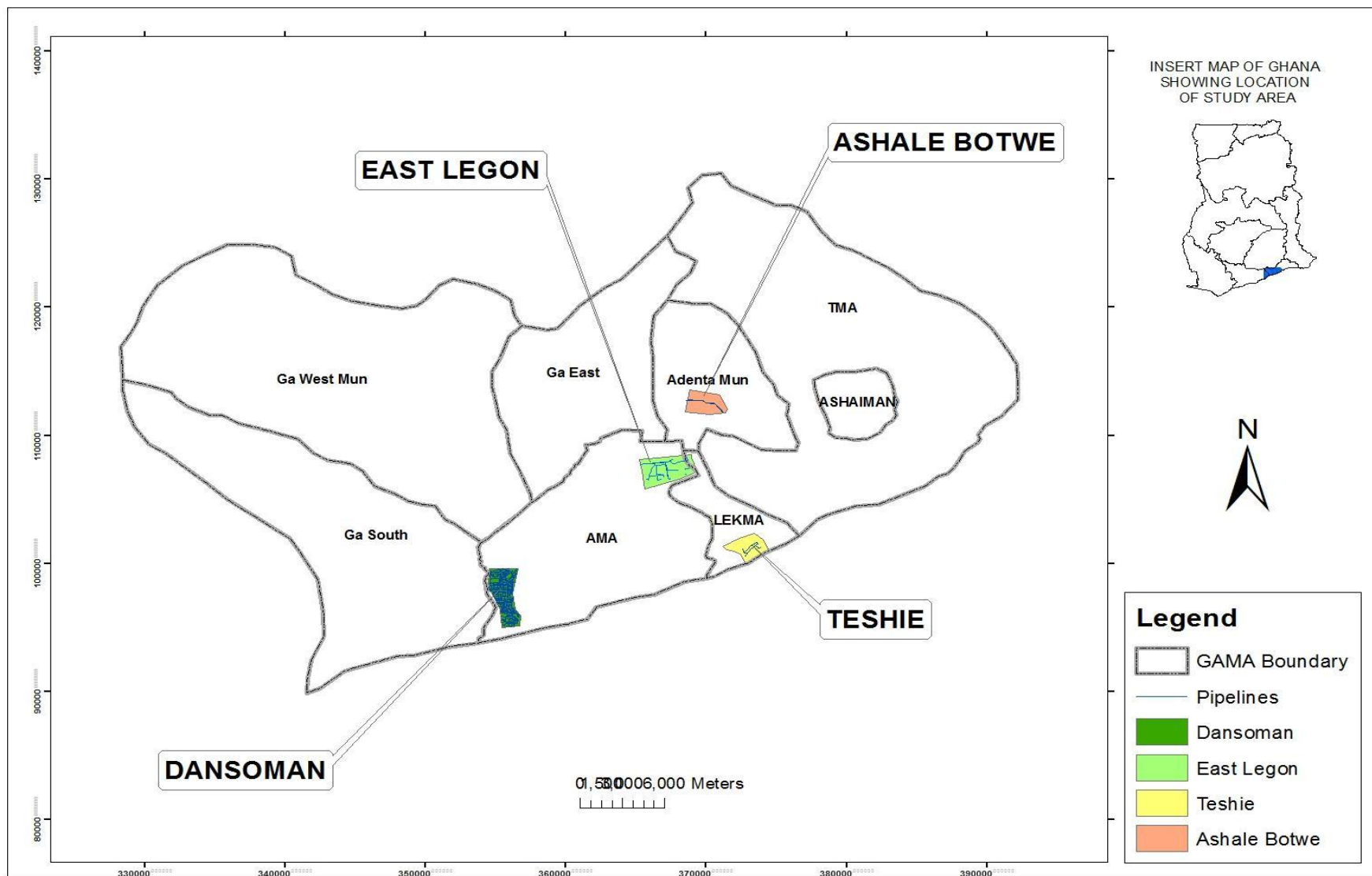


Figure 2. 1: Map of GAMA Showing Key Sampled Sites

Source: Fieldwork, 2011

2.3 Main Data Collection Techniques

The study used both primary and secondary sources of data. For the primary sources, this study employed the mixed method of data collection by combining both quantitative and qualitative methods (Bogdan and Biklen, 2006). This mode of data collection was as a result of the objectives set out for this research which required aspects of both methods. For many years, philosophical purists eschewed the idea of mixing qualitative and quantitative methodologies within a research project (Creswell, 2003). However, other researchers have combined qualitative and quantitative methods, either knowingly or unknowingly, with the intention of best answering a particular research question (Johnson and Onwuegbuzie, 2004). This hybrid approach has become more accepted within education and other social science disciplines (Bryman, 2001; Rzas, 2004; Flowerdew and Martin, 2005; Mayoux, 2006). The use of mixed methods for this research was relevant because it affords an in-depth conceptualization of the research problems.

The secondary data were derived from GIS databases on water production parameters in the form of water abstraction and sales data, current rationing programme and maps on water situation in GAMA. Qualitative data were in the form of interviews with management of Ghana Water Company Limited (GWCL) on issues not clarified in their reports, their past practices and future plans for water service delivery in the country.

As will be seen in this write-up, the first objective was achieved through qualitative methods and secondary data. The second, third and fourth objectives were achieved from mixed methods of data collection in the form of questionnaire administration and focus group discussions of field respondents. In-depth interviews on water and sanitation providers were also done to compare with field responses.

2.3.1 Questionnaire Survey

The questionnaires, semi- structured in form, largely formed the main research instrument used in soliciting responses from households. This was administered through stratified sampling to households to a sample size of 200 respondents, 60 from each community, from East Legon, Ashale Botwe, Teshie and Dansoman Estates (Table 2.1). The target member of each household interviewed was the decision makers. Where decision makers in the household were not available, the most levelheaded person's opinion was sought

Table 2. 1: Design for Household Survey

Study Areas	Sample Pop. for Questionnaires	Focus Group Discussion
Ashale Botwe	60	1
East Legon	60	1
Teshie	60	1
Dansoman Estates	60	1
Total	240	4

⁴Source: Fieldwork, 2011

2.3.2 Focus Group Discussions

Focus group discussions were conducted in the four sampled localities in GAMA. Four (4) focus group discussions, one in each locality were conducted in Ashale Botwe, East Legon, Teshie and Dansoman Estates (Table 2.1). Each group consisted of 5-8 persons of mixed gender. Mixed gender was employed because wastewater reuse is a social phenomenon and not too sensitive to require gender groups. The age group purposively selected was from 30 to 60 years. The

⁴ Even numbers of questionnaires was employed because a large sample size was required for representative statistical analysis

importance of these focus group discussions was to collect spontaneous and detailed qualitative data not clarified during the questionnaire surveys. Some of the issues discussed were cultural attitudes and perceptions of reuse and their willingness to adapt to this emerging technology. This afforded the researcher diverse opinions, attitudes, and motivations of individuals for reuse. Attention was paid to body language, which was to be expected from such a sensitive topic, especially when wastewater is seen as ‘dirty’ water belonging to the ‘gutters’.

It is also important to note that the focus group discussions were conducted in areas classified as poor areas, peri-urban zones and also, wealthy zones because different responses were expected from the different areas. This was because, the availability of water in these areas was different and their coping mechanisms were different. For example, an area like Ashale Botwe hardly received water through their taps and had to constantly resort to tanker services or bore holes considering their locations on the fringes of GAMA.

2.3.3 In-Depth Interviews

Unstructured interviews were conducted with key informants in the water sector, sanitation sector, Accra Metropolitan Assembly, and other policy makers for the purposes of the study. In-depth interviews on wastewater reuse technologies were also conducted with two people identified through snowballing and purposive sampling. Five key informant interviewers were selected from GWCL. They included The Managing Director (Head Office), District Manager and Operations Manager (Accra-East District Office), Senior Water Quality Analyst (Head Office), and Distribution Manager (Accra-North East District Office),. The interviews were held at the Main Head Office in Accra, and District Offices in Legon, Mile 4, Dansoman and La. In each area, one key informant was selected, periodic visits were arranged, and interviews

conducted on water issues, until research was done. Other key informants located in the Geographical Information Systems (GIS) section of Accra East District office of GWCL were also interviewed. These informants provided all the GIS databases needed for the map productions on water, rationing data of Accra and water production figures at Weija and Kpong head works. From the sanitation sector, two key informants were selected on wastewater disposal methods and the future of wastewater in the country. Two interviews were also carried out with officials of AMA and Ministry of Water Resources, Works and Housing (MWRWH) on the plan and sanitation issues in AMA and GAMA as a whole. Lastly, an interview was held with officials of Water Directorate, a subsidiary of MWRWH focused on water policies in the country.

2.4 Pre-Testing of Questionnaires

Pre-tests of questionnaires were done two weeks prior to the actual fieldwork which commenced in July, 2011. These were done in East Cantonments and. During the pre-tests, gaps were identified and these were later rectified for the main study like the difficulty in assessing high-income respondents as most of the residences were walled with security guards at posts who were very unwilling to talk to strangers. Low-income entry was however easier. From the experience, the actual work employed the services of one GWCL personnel in charge of distributing water bills, especially for the high-income areas to help make easy entry into the households. Using his identification card, I was able to conduct fieldwork successfully in the high, middle or low- income areas.

2.5 Secondary Data

Secondary data was sourced from books, journal articles, and reports. They included Global Water Supply and Sanitation Assessment 2000 Report, Environmental Health Watch and Disaster Monitoring Manual, WHO Guidelines for the safe use of wastewater, and GIS

Databases on current water production figures, rationing programme and trends, as well as databases for map productions. The institutions involved included, Ghana Water Company Ltd (GWCL), specifically, it's GIS section, main and district offices, Water Resources Commission, and relevant Ministries and Sanitation Agencies.

2.6 Data Analysis

Generally, most of the findings were presented using graphs, charts, tables, maps and images. The data from the field were analyzed using both qualitative and quantitative techniques. The quantitative data were analyzed using the Statistical Package for the Social Sciences (SPSS), version 16 and STATA Statistical Data Analysis to generate frequency distributions, percentages and cross tabulations.

The chi-square (X^2) distribution test was used to test the significance of the hypotheses. These hypotheses prior to the tests of significance also influenced the choice of study areas to show variations among responses. The binary logistic regression model analysis was also used to generate a model for willingness to reuse wastewater.

Photographs taken were used to discuss field evidence of wastewater reuse and various coping mechanisms in the different study localities.

With respect to the qualitative data, evidence, which was gathered from the field, were transcribed and the results were presented in narratives.

CHAPTER 3 PHYSICAL, DEMOGRAPHIC AND SOCIO-ECONOMIC PROFILE OF GAMA

3.1 Introduction

This chapter introduces the study area, Greater Accra Metropolitan Area (GAMA), and discusses its various characteristics. The themes related to the study are physical features, population growth dynamics, and socio-economic characteristics of GAMA. The specific issues include location and size, geology, climate and hydrology, water resources, housing and social services, sanitation and health and economic activities in the GAMA. Since this is an urban and regional study, it was relevant that the characteristics of the study area are adequately understood to facilitate analysis of the problem from primary information sought from water users in the study area. This will further aid in understanding the interrelationships that exist among phenomena.

3.2 Physical Features of GAMA

In GAMA, the features of significance to the study are those that include location and size, geology, climate and hydrology and water resources. These features highlight the effect they have on water availability and also help identify opportunities and challenges available for wastewater reuse.

3.2.1 Location and Size

Various definitions of Greater Accra have arisen through various studies; notable are those by Yankson *et. al.*, (2004), Songsore *et. al.* (2005), and Songsore *et. al.* (2008). The Greater Accra Region is the smallest region in Ghana with an area of 3,245 km² (GSS, 2005). It is made up of urban and rural areas. About 88 percent of the population of Greater Accra lives in localities defined as urban (settlements with a population of 5,000 or more) and only 12 percent live in small rural communities (SWITCH, 2011). However, GAMA is the area within Greater Accra

Region minus rural areas covering an area of about 1,261 km² (Twum, 2002; Yankson et. al, 2004; Songsore et. al. 2005; Songsore *et. al.* 2008 and Adank et. al. 2011). This area is the focus of the study.

The GAMA has gone through various transformations in terms of divisions. It was formally divided into three districts, Accra Metropolitan Area (AMA), Tema Municipal Area (TMA) and Ga District. As shown in Figure 3.1, the GAMA now consists of eight metropolitan and municipal areas namely Accra Metropolitan Area (AMA), Ledzekuku-Krowor Municipal Area (formerly under AMA), Tema Metropolitan Area (TMA), Ashaiman Municipal Area (formerly under TMA), Adenta Municipal Area (formerly under TMA), Ga East Municipal Area, Ga West Municipal Area, and Ga South Municipal Area (formerly under Ga West).

Within GAMA, the four areas chosen for most parts of this research include Dansoman Estates and East Legon, which are in Accra Metropolitan Area (AMA), Ashale Botwe in Adentan Municipal Area and Teshie in Ledzokuku-Krowor Municipal Area.

The Metropolitan and Municipal Assemblies derive their mandate from the Local Government Act of 1993 (Act 462). The structure of these assemblies is also spelt out in the act. By this legislative instrument, the Assemblies are the highest political authorities mandated to govern a municipality or metropolitan area and to provide basic infrastructure and services to support the social and economic development of the area. The area under the assemblies is sub-divided into sub-metros, which are in turn further divided into town or area councils and unit committees (Adank *et. al.*, 2011).

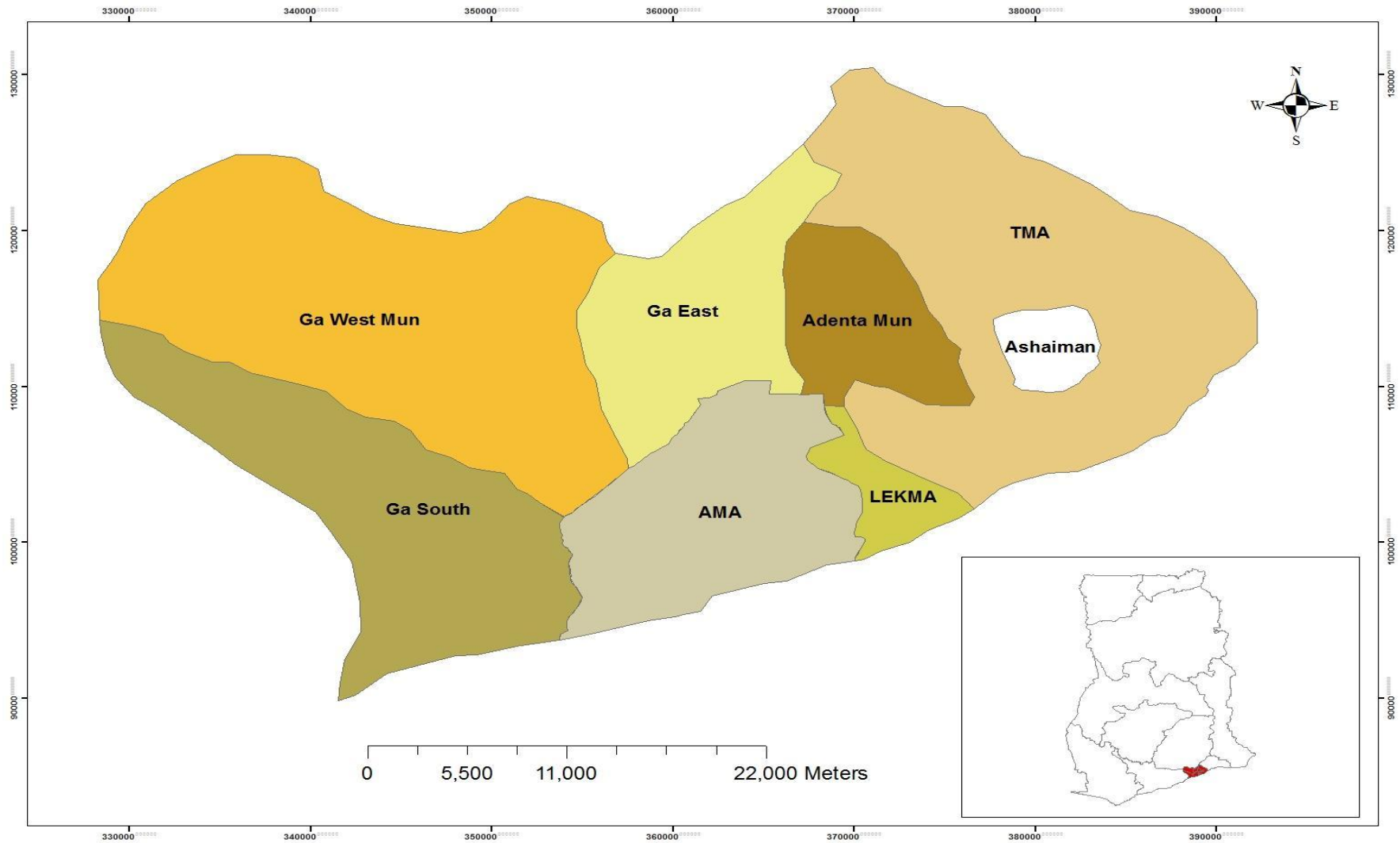


Figure 3. 1: Map of GAMA Showing Administrative Districts

Source: Songsore et al, 2008; Survey Department 2011; Fieldwork, 2011

3.2.2 Climate and Hydrology

GAMA lies in the dry equatorial region of Ghana (Dickson and Benneh, 1988). The average annual rainfall is about 730 mm, which falls primarily within Ghana's two rainy seasons (See Figure 3.2). The first rainy season begins in May and ends in mid-July. The second season begins in mid-August and ends in October. Rains usually fall in short intensive storms and give rise to local flooding where drainage channels are obstructed (GMET, 2009). Drainage channels can be obstructed because of the type of infrastructure in the region. Due to technological developments in most parts of GAMA, most land surfaces are cemented, paved or tarred. So some run-offs which would have otherwise seeped into the soil to the water table, now have to find new channels to flow. Accumulation of this kind of water over a short period of time results in flooding, especially if there are unapproved structures in its way. This consequently changes the underground hydrology of the region, as more water is lost to the sea.

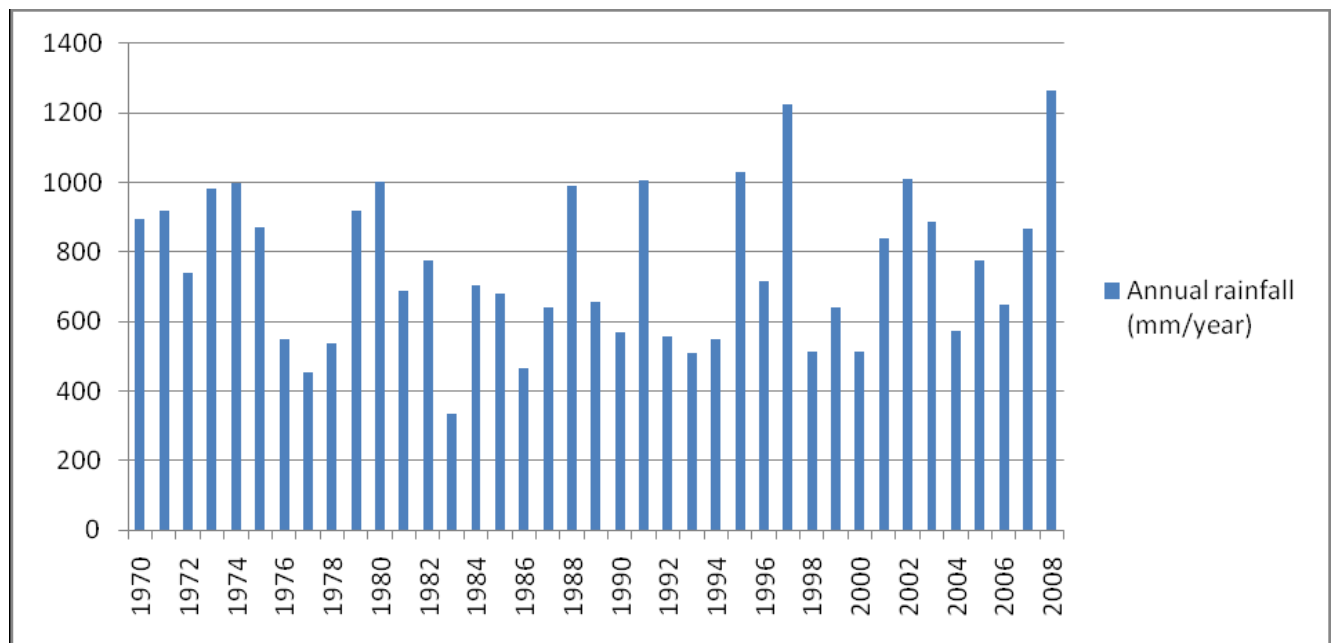


Figure 3. 2: Annual Rainfall from 1970 to 2008 in GAMA

Source: GMET, 2009

There is very little variation in temperature throughout the year. The mean monthly temperature ranges from 24.7 °C (76.5 °F) in August (the coolest) to 28 °C (82.4 °F) in March (the hottest), with an annual average of 26.8 °C (80.2 °F). It should be noted, however, that the "cooler" months tend to be more humid than the warmer months. As a result, during the warmer months and particularly during the windy harmattan season, the city experiences a breezy "dry heat" that feels less warm than the "cooler" but more humid rainy season (Ghana Districts, 2010).

3.2.3 Underlying Geology and the General Water Holding Capacity

3.2.3.1 Underlying Geology

Geological studies have shown that the region is not well endowed with mineral resources and possesses only granite, clay and salt (Ghana Districts, 2010). The geology is predominantly that of the crystalline basement rocks (Kesse 1985). The geological formations are the Dahomeyan System, the Togo Series and Accraian Series (Adank et al. 2011).

The Dahomeyan Series cover the greater part of GAMA. It occurs as alternating belts of acidic and basic gneisses. Accraian formations are sedimentary rocks found mainly in the Accra Metropolitan Area. The Togo series can be found at the foothills of the Togo-Akwapim ranges. The coastline of GAMA comprises a series of resistant rock outcrops and platforms and sandy beaches near the mouth of the lagoons (Adank et al. 2011). The soils have low organic contents with shallow top soils, which limit the capacity for crop production (Ghana Districts, 2010).

3.2.3.2 The Drainage System in GAMA

The total drainage area of the Densu Basin part of which is located within GAMA is about 2,500 km² (WRC, 2008). It is divided into two sections: above and below the Weija dam. The northern section of the basin, which extends 100 km inland along the Densu River and its tributaries, is hilly. The southern section of the basin consists of low-lying land, which is largely urbanized now. The Densu River runs from its source in the Atiwa Range near Kibi to the Weija Reservoir, before entering the Sakumo I Lagoon and Panbros salt pans and finally the Gulf of Guinea (WRC, 2008).

The Lafa stream flows into the lagoon and drains much of the western area of Accra including Dansoman, Kwashieman, McCarthy Hill and Awoshie. The Korle-Chemu catchment covers an area of about 291 km² (Nyarko, 2002). The principal streams that drain the catchment are the Odaw River and its tributaries, the Nima, Onyasia, Dakobi and Ado (AMA, 2006).

The Odaw river drains Dome, Legon, Achimota, Ring Road Industrial Area and the high density, low income areas of Nima, Maamobi and Accra Newtown.

The Kpeshie drainage basin covers a relatively small catchment area of about 62.6 km² (Nyarko, 2002). Streams in the catchment empty directly into the Kpeshie Lagoon, which is the principal outlet to the sea.

The Songo-Mokwe catchment is the smallest drainage basin in the AMA. It covers about 31 km² (Nyarko, 2002), draining the area of Teshie. Two main streams drain the area flowing into the Mokwe and Songo lagoons. Much of this catchment is undergoing residential development (AMA, 2006). Finally, the Sakumo II catchment mainly drains the Tema Municipal Area and

discharges most of the drained water in the Sakumo II lagoon. It covers an area of about 280 km² (Nyarko, 2002 cited in Adank et. al., 2011).

3.2.4 Water Resources in GAMA for Potable Use

The location of GAMA is at the downstream end of the Volta and the Densu basins, from where large amounts of water can be abstracted. The two main types of fresh water resources for potable use are surface and ground water. The major uses of fresh water in GAMA are for agriculture, industry, domestic and hydroelectric power generation. Water withdrawals by sector in 2000 were agriculture (48%) industry (15%) and 37% for domestic uses (Ghana Environment Outlook Report, 2006). In terms of consumption, the main uses of water in Ghana are household water supply, irrigation and livestock watering. The main non-consumptive uses are inland fisheries, water transport and hydropower generation (NWP, 2007). Based on surface water resources alone, the consumptive water demand for the year 2020 has been projected to be 5 billion m³ (Ghana Environment Outlook Report, 2006). With respect to irrigation, the projected demand by 2020 is about 400,000m³, to cover a projected area of 100,000 hectares. Many impoundments have also been created to store run-off for many purposes like agriculture. (National Water Policy, 2007).

3.2.4.1 Surface Water Resources to GAMA

It has good surface water resources for harnessing for potable water supply, irrigation and other sources if properly managed. There are a number of river basins partly or fully located in GAMA. The main ones serving GAMA are the Volta and the Densu basins. As the population of the Greater Accra Metropolitan Area depends to a large extent on water from the Volta Basin, located outside the boundaries of GAMA, this catchment is considered here. Only part of the

Densu Basin is also found in GAMA (Adank *et. al.*, 2011).

The Weija dam on the Densu river, located some 20 km from the centre of the Accra is one of the main sources of water supply for the Greater Accra Metropolitan Area. The dam was initially realized in 1952 to supply potable water for Accra and was reconstructed in 1978. The maximum surface area at 15.24m of the impoundment is 33.59 km². The optimal safe yield from the system is 272,765m³/day (about 0.10 x 10³ m³/year) and a volume of impoundment of 212,546 m³. The mean inflow is 54.2 m³per second at the peak of the rainy season. The mean annual run-off is 0.5 million cubic kilometres per year (about 16 m³/s) (Adank *et. al.*, 2011).

The other main source of water supply for Accra, Kpong Dam on the Volta Basin is located entirely outside the Greater Accra Metropolitan Area. It covers six countries: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Togo and has a total area of 400,000 km². The three main rivers, the Black Volta, the White Volta and the Oti discharge into the world's largest artificial lake: the Akosombo Reservoir - more commonly named Volta Lake (Adank *et. al.*, 2011).

Friezen et al (2005) estimate the coefficient of variation for rainfall in the Volta Basin to be only 0.08 (1931-1995), with an average of 400 x 10³ m³ /year. The coefficient of variation in run-off is however estimated to be far higher: 0.38, with an average discharge of 43 x 10³ m³/year (1931-1995). The level of inflow was considerably below this average in 1983 (about 7.6 x 10³ m³), in 1997 (26.5 x 10³ m³) and in 2006 (23.8 x 10³ m³), which resulted in lower water levels at Akosombo and the electricity crises of 1984, 1998 and 2007 (Ameko, 2007). The quality of raw water from the Volta is better than that of the Densu due to two large dams that serve as sedimentation basins for the raw water. However, as the population in the surrounding villages continue to grow, the situation is likely to worsen both at Weija (Densu) and Kpong (Volta) in the near future (Uusitalo, 2002).

3.2.4.2 Ground Water Resource

The water table in GAMA varies between 4.8m and 70m (Nyarko, 2002). The mean yield of boreholes in the Dahomeyan series with a mean depth of 39m, have a mean yield of $3\text{m}^3/\text{hour}$, ranging from 0.54 to $12\text{m}^3/\text{hour}$. The yield of boreholes in the Togo series with a mean depth of 44m ranges between 0.42 and $31.5\text{m}^3/\text{hour}$, with a mean value of $5.6\text{m}^3/\text{hour}$ (WRI, 1999). Boreholes in the Accraian Series have an average yield of $3.9\text{m}^3/\text{hour}$ (Ghana Mining Portal). According to Darko (2005), the probable yield in zones with negative transmissivity anomalies would be $0.36\text{m}^3/\text{hour}$ in the Dahomeyan and $0.6\text{m}^3/\text{hour}$ in the Togo series formation. In areas of positive anomalies, the expected yield would amount to $2.1\text{m}^3/\text{hour}$ and $7.2\text{m}^3/\text{hour}$ in the Dahomeyan and Togo Series formations respectively.

According to Adank *et. al.* (2011), it is difficult to give an estimate of the volume of suitable groundwater that could be extracted in a sustainable way. Taking a conservative estimate for ground water recharge of four percent of the rainfall, and using an annual rainfall of 756 mm, the recharge can be estimated to amount to about 30mm. Over the entire Greater Accra Metropolitan Area, they reported that, it would mean a total recharge of about $0.038 \times 10^3\text{m}^3/\text{year}$. In that case, a total of 1,116 boreholes with an average yield of $3.9\text{m}^3/\text{hour}$ ($93.6\text{m}^3/\text{day}$) could in theory abstract ground water, without deflating the groundwater resources.

Ground water salinity increases from north of the GAMA to the south, towards the coast. The origin of the high salinity levels of the groundwater can be attributed to several probable causes. According to Kortatsi and Jørgensen (2001), halite dissolution from the soil zone as a result of aerosol deposition seems to be the main cause of groundwater salinity. They identify saline water intrusion as the main cause for salinity of the groundwater close to the coast. They also asserted that, evaporative concentration of surface waters contributes to salinization on a small scale.

3.3 Anthropogenic Factors Affecting Water Supply

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support human use, such as drinking water and/or undergoes a marked shift in its ability to support its constituent biotic communities such as fish (West, 2006). Natural phenomena such as storms, algae blooms, and earthquakes also cause major changes in water quality (West, 2006). Pollution affects both surface and ground water. Groundwater pollution is pollution from sources that do not affect surface water directly like oil spills and chemicals contaminating soil and consequently the aquifer below defined as toxin plume (Hogan, 2010).

Sources of surface water pollution are grouped into two categories based on their origin; point and non-point sources. Whereas point sources refers to contaminants entering a waterway from a single identifiable source such as a pipe or a ditch from a sewerage treatment plant, a factory or a city storm drain, non-point source pollution refers to diffuse contamination from multiple sources. It is usually the cumulative effect of small amounts of contaminants gathered from a large area. An example is the leaching out of nitrogen compounds from fertilized agricultural lands (Hogan, 2010).

The Population and Housing Census (PHC) statistic shows that, the population density in the Densu Basin is 240 persons per km², considerably higher than the national average of about 100 persons per km². The main occupation of inhabitants of the basin is agriculture. Due to uncontrolled human activities that generate waste, untreated sewage, fertilizer and pesticide runoff, very high colour, turbidity and nutrient levels have been identified in the Densu river (WRI, 2003). Raw water at the Weija dam has been reported to have a biological oxygen demand (BOD) of 10 mg/l (which is high considering that moderately polluted rivers generally have a BOD of 2-8 mg/l) and a chemical oxygen demand (COD) of 49 mg/l (Lundehn and Morrison, 2007). As a result, a general trend of water quality deterioration in the Weija Lake

is observed (Ansa-Asare and Asante, 2005, and Asante et al, 2008).

Studies done by Awuah and Fiakuma, (2007), also shows that, the catchment area of the Odaw river is densely populated and has a large concentration of industries including Ghana Breweries Limited, and vehicle repair workshops. Accordingly, the water of the Odaw is highly polluted. The BOD measured is 240 mg/l and the COD 2560 mg/l, which is far in excess of the EPA norms of 50mg/l and 250mg/l respectively (Awuah and Fiakuma, 2007).

The Odaw discharges into the Korle Lagoon which eventually empties into the sea near Korle Gonno. Siltation of the Lagoon is, to a large extent, caused by flood waters which erode the commonly unpaved areas in the catchment and transport the silt into the Lagoon (Karikari, et. al., 2006). A survey conducted in April 1997 indicated that the entrance of the Korle Lagoon is moderately to grossly polluted as evidenced by the physical, chemical and bacteriological characteristics (Karikari, et. al., 2006). The Korle Lagoon has been mentioned as one of the most polluted water bodies on earth (Bourgoing, 1996; Boadi and Kuitunen, 2002). Causes for this include discharge of domestic and industrial effluents from inland and the operations of the sewage outfall in the vicinity of the Lagoon entrance. At high tide, the effluents from the outfall are back-washed into the Lagoon. The extremely high levels of Biological Oxygen Demand (BOD), suspended solids, coliforms and ammonia-nitrogen of the raw sewage are an indication of the extent of organic pollutants introduced into the sea. However, according to Karikari, et. al., (2006), samples collected 500m offshore showed good water quality, which can primarily be attributed to dilution. Therefore, although the outlet of the Lagoon and immediate environment are moderately to grossly polluted, because of discharges from the sewage outfall and from inland, this negative impact is significantly reduced less than one km offshore as a result of the dilution effect of the open ocean. This process is important for artisanal fisheries, such as beach

seining, which take place within the zone less than one km from the beach.

Groundwater pollution occurs when there is a contact issue with the underground water table in refuse pits, septic tanks and soak-away caused by human beings. These occur especially when the water table is shallow. The contents of these are dissolved by the water and become solutes in the groundwater. These solutes according to several studies will be in solution several years (EPA, 2006). Most concern over groundwater contamination has centered on pollution associated with human activities as found in Kwabenya and Pantang (Personal comm., AMA, 2011). Human groundwater contamination can be related to waste disposal including private sewage disposal systems, land disposal of solid waste, municipal wastewater, wastewater impoundments, land spreading of sludge, brine disposal from the petroleum industry, mine wastes, deep-well disposal of liquid wastes, animal feedlot wastes, and radioactive wastes. It could also be indirectly related to waste disposal (accidents, certain agricultural activities, mining, highway deicing, acid rain, improper well construction and maintenance).

3.4 Population Growth and Physical Expansion

The Greater Accra Region as at the 2010 Population and Housing Census (PHC) results is estimated to be home to about 4 million people, making it the largest metropolitan conglomeration in the country by population (PHC, 2010). The population of Greater Accra increased from 491,817 in 1960 to 2,905,726 in 2000 and currently 4,010,054 in 2010. It has the second largest population, after Ashanti Region (4,780,380), and its share of the total population of the country has steadily increased from 7.3 per cent in 1960 to 15.4 per cent in 2000 and to 16.1 per cent in 2010 (GSS, 2000).

The GAMA, the area within Greater Accra minus Dangbe East and Dangbe West has a population of 3,756,423 as at the 2010 Population and Housing Census. According to the 2000

Population and Housing Census, the study areas chosen for the household survey include, Ashale Botwe, with a total population of 11,974, whereas East Legon, Teshie, and Dansoman Estates had populations of 7681; 8897; and 49,230 respectively.

Analysis of the region shows that Greater Accra has remained the most densely populated region in the country since 1960. The population density per square kilometer increased from 167 persons in 1960 to 441 persons in 1984 to 895.5 persons in 2000 and currently to 1,236 persons per square kilometer in 2010. The intercensal growth rate of 4.4 per cent between 1984 and 2000 for the region was much in excess of the national average of 2.7 per cent per annum (GSS, 2002). Further, the growth rate between 2000 and 2010 for the region dropped to 3.36 per cent (GSS, 2002).

The sex ratio increased slightly from 96 males in 1984 to 98 males in 2000 and then dropped to 93 males to 100 females in 2010. The factors, according to Population and Housing Census responsible for the excess of females include male out-migration and higher male mortality (GSS, 2000).

The region's age structure is still a youthful one, characterized by a somewhat high fertility, which has begun to show signs of a steep downward trend. The proportion of persons under 15 years has decreased sharply from 41.5 per cent in 1984 to 33 per cent in 2000, giving rise to a corresponding increase in the proportion of the aged (65 years and older) from 2.6 per cent in 1984 to 3.9 per cent in 2000 (GSS, 2000).

The fall in fertility has affected the dependency ratio, which has decreased from 79.1 in 1984 to 58.7 persons in 2000 in the dependent ages for every 100 adults. The corresponding increase of

persons aged 15-64 may be due in part to in-migrants looking for jobs in AMA and Tema, the two most industrialized districts (GSS, 2000).

3.5 Socio-Economic Characteristics of GAMA

The goal of a socio-economic study is generally to help bring about socio-economic development, usually in terms of improvements in metrics such as GDP, life expectancy, literacy, levels of employment, etc (Ghana Ministry of Finance and Economic Planning, 2008). Some of the socio-economic characteristics discussed include housing and social services, sanitation, health and economic activities of the residents of GAMA.

3.5.1 Housing and Social Services

A household is defined as a person or a group of persons, who live together in the same dwelling, share the same housekeeping arrangements and are catered for as one unit (Lampsey, 2010). Housing within GAMA can be grouped into three broad categories: the low-income, middle-income and high-income areas (Songsore, 2008). The low-income residential areas may be divided into indigenous and non-indigenous (dominantly migrant) areas. The low-income indigenous housing areas in GAMA comprise Osu, Jamestown, Adedekpo, Chorkor, La, Teshie and Nungua.

The low-income migrant housing areas include Sukura, Kwashieman, Odorkor, Bubiashie, Abeka, Nima, Maamobi and Chorkor and other emerging settlements. Altogether, these areas accommodate about 58% of Accra's total population. Most of the city's informal businesses are located in low-income areas, which are the first place of abode for any new job-seeking migrant. Conditions are nonetheless much worse in the low-income areas, with very high pressures on

facilities. On average, there are about 30 people per toilet, 48 per kitchen and 22 per bathroom in the Accra slums. This is due to a combination of inadequate facilities, continual population growth and the conversion of facility spaces to other uses (GSS, 2002).

Parts of inner city Accra comprise a mixture of very low-density development with under-utilized service infrastructure on the one hand, and indigenous, low-class, and high-density development with depressed conditions and overstretched infrastructure services on the other (GSS, 2002). The rapid growth of Accra has led to the neglect of some of the old indigenous settlements, whilst efforts are being made to provide the newly developing suburban areas with services and infrastructure to cater for the needs of the middle-income earners mostly found there. The result is that the older indigenous areas of Accra, such as Ga Mashie, are experiencing decay.

The middle-income areas of Accra are predominantly populated by business, administrative and professional families. Much of the housing in these areas has been provided by the state, parastatal and private sector organizations and individuals. The middle-income areas include Dansoman Estates, North Kaneshie Estates, Asylum Down, Kanda Estates, Abelempke, Achimota and Tesano. Usually, these areas, unlike the low-income areas, are planned developments, with adequate infrastructure services. Building materials and general housing conditions are of better quality. The middle-income group comprises 32% of the city's population.

The high-income areas provide housing for the remaining 10% of the population. They include areas like North and West Ridge, Ringway Estates, North Labone Estates, Airport Residential Area, Roman Ridge, and East Legon. These areas are all planned and have well developed

infrastructure with spacious and landscaped ground in sharp contrast with, particularly, the low-income areas.

There is also high and middle income peripheral areas like Hatso, Adenta, Taifa, Mallam, and Ashale Botwe where development of engineering infrastructure is not yet complete. These areas developed ahead of infrastructure and consequently lack almost all utility services such as water supply (Ghana Districts, 2010). Peripheral residential development in Accra is usually haphazard, with barely sufficient infrastructure to support it. There are also large numbers of uncompleted houses, interspersed with pockets of undeveloped land, which are often subject of litigation, due to the inability of organizations and individuals who own them to complete or develop them due to lack of funds. It can therefore be inferred that, although in some instances low-income areas have exhibited poor housing conditions, the general quality of housing in Accra is significantly better than that of other urban areas and Ghanaian housing in general. As at the 2000 PHC, the total number of households in the region is 626,611 giving an average household size of 4.6.

3.5.2 Sanitation and Health

The most pressing environmental health problems today in terms of deaths and illness worldwide, are those associated with the poor home and neighbourhood environments, and 80% of all deaths in developing countries are water related (WHO, 2000; Songsore, 2004). The WHO posits that improvement at the household and community level could lower the incidence of major killer diseases by 40% globally (UNDP, 1998; WHO, 2000). However, Gleick (2002) stresses that if no action is taken to address unmet basic human needs for water, as many as 135 million people will die from these diseases by 2020. Moreover, even if the explicit Millennium Goals announced by the United Nations in 2000 are achieved, between 34 and 76 million people

will still perish from water related diseases by 2020.

The level of sanitation coverage for GAMA too is very low and this is reported to be a factor in the high levels of morbidity and environmental pollution (EPA, 2006). For example, in Ghana, only 41.5% of households have toilet facilities provided in or around their houses, and in most cases are shared with other households. Of these toilet facilities, the pit latrine serves 22% of households, WC, 8.5%, KVIP, 6.9% and bucket or pan latrine, 4.1%. For the rest of the households 31.4% use a public facility, while 20.2% had access to no specified facility. For the disposal of solid waste, 82.6% of households use either a public dump- site or elsewhere at their convenience, which could be a stream or open gutter or on some undeveloped plot of land (EPA, 2006). Due to limited industrial development, domestic effluent and urban run-off contribute the bulk of wastewater generated in Ghana.

In Accra, the state of sanitation is highly unsatisfactory caused by diverse groups in society, thus according to Songsore et al, 2009, p.53:

“In terms of spatial trends, we recognize the overall impact of young migrants moving into the city often with junior secondary school education but lacking the skills for employment in the highly competitive labour market spontaneously colonizing spaces for street vending and shack settlements. All these together with the increasing population in especially low-income high density areas in conditions of growing poverty pose enormous waste management problems and shelter poverty”.

It is worth mentioning that public toilets serve most areas in the city. These public toilets found in sections of the Municipality have a shift from its original purpose of serving visitors to the communities to its current use by serving households. In other words, the public toilets are now the inconvenient substitute for majority of households who lack domestic toilets. The toilets themselves are a menace to the urban poor because in most instances they are far too few and far too poorly managed for explosive populations (www.ruaf.org).

Songsore, again, in 2009 observed in an earlier study in 2001 that environmental burdens associated with sanitation facilities are minimal in planned residential areas because of zoning regulations as compared to unplanned low-income areas. These therefore lead to exposure to risks associated with ill health. The AMA has however initiated measures to replace very old public toilets with new and modern ones, in line with modern trends. The challenge however relates to supply of water to these new toilets due to the generally poor water supply network in the Municipality.

Solid waste management also remain a challenge confronting the Municipality despite efforts so far made. Certain areas are characterized by choked drains, indiscriminate waste disposal and uncollected refuse in central waste containers (Pacione, 2005; Oteng-Ababio, 2007). However, large proportions of these wastes are biodegradable making decomposition quite easy. Notable factors accounting for the waste management problem include; poor conceptualization of sanitation and lack of adequate sanitary facilities, ignorance and irresponsibility of individuals, households and communities, lack of community action, continuously increasing number of squatters, lack of regular budgetary allocation for sanitation and virtual absence of fee based service provision in low-income areas. Currently, the waste management system available, example, Zoomlion, provides for door-to-door service, which attracts service fees, which is prominent in affluent and well-planned areas, while communal container services are common in low-income areas which attracts no fees from beneficiaries (Kumashie, 2012). All waste collected are sent to semi-controlled landfill sites within the Municipality known as the Teshie Compost Plant or Fertilizer Factory. However, little recycling of plastics and polyethylene occurs with private recycling companies (Obirih-Pareh and Post, 2001; Oteng-Ababio, 2007). It has been amply demonstrated that, the current system is not sustainable due to the non-payment for

communal container service, which is estimated to constitute over 80% of service cost, a situation that has resulted in high financial burden for the Assembly. Other problems such as irregular payment of service providers, non-performance by service providers, etc. are all related to financial constraints of the authorities (EPA, 2006; Van der Geest and Obirih-Opareh, 2008)

Wastewater disposal taking place at the point of waste production, within individual houses without transportation, is termed as on-site disposal. Whilst with off-site disposal, there is a transportation element. On-site methods include dry methods (pit latrines, composting toilets), water saving methods (pour-flush latrine and aqua privy with soakage pits) and methods with high water rise (flush toilet with septic tanks and soakage pit, which are not emptied). Off-site methods are bucket latrines, pour-flush toilets with vault and tanker removal and the conventional sewerage system. Conventional sewerage systems can be combined sewers (where wastewater is carried with storm water) or separated sewers (www.ruaf.org).

In Accra-Tema, there are about 22 sewerage systems and sewage treatment plants serving institutions and hotels, but only a few are operating and maintained in accordance with designers' intentions (Akuffo, 1998; EPA, 2001). These plants serve in total about 5-7% of Accra's population. The largest plant, which started operations in 2000, works with an upflow anaerobic sludge blanket (UASB). The plant can handle about 16,000 m³/day but receives less than 5000 m³/day due to the small size of the sewerage. After a one-year test run, the plant was handed over to the Municipality and broke partially down in 2003/2004.

Faecal sludge treatment plants in Accra are no better. The main plants at Achimota with dumping rate of about 250 m³/day; Korle Gonno (50 m³/day) and Teshie-Nungua (80 m³/day) are badly maintained or out of order. Untreated faecal sludge ends up being disposed off in nearby streams

(Achimota, Teshie) or in the seashore, as is the case at Korle Gonno with the tipping area, also called “Lavender Hill”. Currently, more than half of Accra’s collected faecal sludge is dumped into the ocean.

Like in Kumasi, grey water is mostly transferred through storm water gutter into drains and streams. Accra’s major wetland, the Korle Lagoon, receives ‘fresh’ water through the Odaw stream, which is the main urban storm water drain with a catchment area covering more than 60% of the city. Due to Accra’s limited sanitation infrastructure, the Odaw river and the Korle lagoon receive a vast amount of wastewater as well as solid waste (Boadi and Kuitunen, 2002).

Wastewater treatment can also be done on-site or off-site. An example of on-site treatment is with septic tanks. There are three broad levels of treatment: primary treatment where gross particles and objects, sand, grit, suspended solids are removed. Secondary treatment is the removal of organic matter and tertiary treatment is when nitrogen compounds, phosphorus compounds, and pathogenic microorganisms are removed. The treatment can be done mechanically like in trickling filters, activated sludge methods or non-mechanically like in anaerobic treatment stabilization ponds. (www.ruaf.org). The last known treatment method, is the Biological Treatment System. This level of treatment involves utilizing the biological content in grey water to reduce microbial contamination, suspended solids, turbidity and nutrients (nitrogen and phosphorous). The treatment process, according to (NEERI, 2007) requires a significant level of automation and energy to power the aeration technology as well as pumps and disinfection systems.

CHAPTER 4 EXISTING POTABLE WATER DEMAND AND SUPPLY PATTERNS

4.1 Introduction

This chapter presents the socio demographic characteristic of respondent collected from the four communities and further analyses of the water demand and supply situation in the study area, GAMA.

4.2 Socio-Economic Characteristics of Respondents

Out of the 240 respondents interviewed, the study revealed more female respondents (59.2%) to male responses (40.8%). In terms of ethnic distribution, Ga- Adangbe represented 41.2% forming the highest ethnic bracket, followed by Akan (25.4%), Ewe (19.2%), other tribes (10%) and Mole Dagbane (4.2%).

The age of the respondents ranged from 20 to 81+ years, with more than half of responses in the 20-40 year group, representing 53.3 % followed by 41-50 (17.9%) and 51-60 (15.8%) age brackets as shown in Table 4.1. Responses were lower in the 61-70, 71-80 and 81+ years, which recorded percentages of 10, 1.2 and 0.8, respectively.

Table 4. 1: Socio-Demographic Characteristics of Respondents

Characteristic	Frequency	Percentage (%)	
Age	20-30	63	26.2
	31-40	65	27.1
	41-50	43	17.9
	51-60	38	15.8
	61-70	26	10.8
	71-80	3	1.2
	81+	2	0.8
	Total	240	100
Religion	Christian	191	79.6
	Muslim	27	11.2
	Traditional	1	0.4
	Other	21	8.8
	Total	240	100
Educational level	None	1	0.4
	Non-formal	2	0.8
	Primary	10	4.2
	Middle/JSS	39	16.2
	Secondary	72	30.0
	Tertiary	116	48.3
	Total	240	100
Income	<Gh 200	56	23.3
	Gh 200 - 500	54	22.5
	Gh 500 - 1000	41	17.1
	Gh 1000 - 1500	25	10.4
	> Gh 1500	25	10.4
	other	39	16.2
	Total	240	100.0

Source: Fieldwork, 2011

Data on religion was collected in the sampled localities, because religion is thought to influence reuse patterns. As a result, respondents views were sought based on their religious affiliation. Christians formed the largest group (79.6%), followed by Muslims (11.2%) and Traditional Religious practitioners (0.4%) (Table 4.1).

From Table 4.1, majority of respondents had attained some form of formal education (98.8%), with tertiary education representing 48.3%, secondary (30.0%), middle/JSS (16.2%), primary (4.2%), non-formal (0.8%) and none (0.4%), in that order.

In terms of income, those who earned less than Gh¢200 represented 23.3%. Others, earning between Gh¢200- Gh¢500 constituted 22.5%, followed by Gh¢500-1000, Gh¢1000-1500, > Gh¢1500 and 'other' category representing 17.1%, 10.4%, 10.4% and 16.2%, respectively. The composition for the 'other' category were students and pensioners who are not employed and not on salary (Table 4.1).

4.3 Water Demand Patterns

A fundamental concept in economics is the law of supply and demand. According to Stephenson (1999), this concept can be applied to theoretical supply and demand for water. At higher prices, producers would be willing to supply more, but consumer demand would decrease. Alternatively, at lower prices, consumers would demand more, but producers may cut back on supply if the system is operated by private enterprise without a social component. Still at lower prices, people will buy and use more water, but there is a limit on how much water anyone can use, even if it is free (Stephenson, 1999).

In spatial research, a basic concern is with the location, distribution and areal extent of phenomena. Environmental resource analysis manifests itself with regard to the appraisal of resource supply and demand in the form of inventory. A host of pertinent questions therefore arises: Where is the resource, how much is there, what is the condition, how available are they, what is the demand for them, how will changing prices, technologies and value affect future demand and what opportunities exist to improve productivity (Mitchell, 1989).

Focusing on water, the difficulties encountered in its research are revealed by studies of water demand. Many researchers, including Sewell and Bower (1968), suggest that identification of relevant variables to the study of demand is one of four key problems faced by researchers. The other three are selection of an appropriate time horizon, consideration of uncertainty and consideration of short-run variability. With reference to variables, they argued that demand for water is a function of five variables: population, nature of the economy, technology, social tastes and policy decisions (Mitchell, 1989).

Whiles these variables are easy to identify, they are difficult to measure. Population estimates require significant assumptions to be made to derive estimates for information on sex, age, numbers, migration, income, and employment. Technological changes may influence water demand in four ways, including development of new products, new processes, new or different raw materials and improved methods for handling water. Changes in social tastes and policy decisions are equally difficult. A number of approaches adopted regarding assessing their impact are to hold them constant (Young et al. 1972; Mitchell, 1989; Khouzam, 2003).

Mfalila (2000) and other researchers contend that, for a long time, the traditional approach to water resource management focused on developing new supplies in addressing increasing water demands, without critically implementing policies and programmes for efficient water use from existing schemes such as wastewater reuse. These existing schemes form the demand side of the equation (Mfalila 2000; Savenije and van der Zaag, 2002; Butler and Fayyaz, 2006; Chigumira and Mujere, 2007). This has been the situation in Ghana and justifiably so, because access to potable water is a huge challenge (Awuah, 2007; Kessie, 2007; TAHAL, 2008). The supply approach has serious consequences on sustainable water management, since it considers water as a near finite commodity.

Analysis of the history of water supply and coverage over time (which will be elaborated in the ensuing sections) shows that there are huge demands for water in the Greater Accra Metropolitan Area, which even grow more than the population growth. An important cause of this problem is the economic growth that is still expected to be the major cause of heightened demand for water if appropriate measures are not put in place. While water as a resource is generally abundant, many factors, like financial resources required to develop it into potable use, are lacking. This makes the resource unavailable and sometimes, inaccessible. In Accra, the provisional result of the 2010 Population Census shows that GAMA has a population of about 4.0 million with the transient population of about 1.3 million (GSS, 2012). With a per capita consumption estimated at about 120-140l/c/d for urban dwellers (GWCL, 2011) and using the lower figure, it is envisaged that 469,171.680m³ water should be supplied to Accra daily. However, the water supply to GAMA as at 2010 (Fieldwork, 2011) is 404,841.00m³/day, leaving a considerable deficit of 64,330.68m³/day (GWCL, 2011). This meant that sections or all areas of GAMA do not receive constant water supply, in spite of the perennial rationing schedule with corresponding inconvenience for consumers.

In view of the above, an analysis of the current demand and supply patterns with respect to water availability and accessibility within the Greater Accra Metropolitan Area was undertaken which served as a platform to analyze coping mechanisms, such as wastewater reuse as an alternative source of water in the ensuing chapters for different residential, industrial and agricultural activities. The emphasis of this section is to view water for potable use in terms of its demand for municipal use in the GAMA. In the ensuing sub-sections, the discussion will focus on factors influencing demand in the context of increasing climate change and variability, uneven demand coverage, changing trends, consumer satisfaction, community perception and assessment of quality of potable water.

4.3.1 Determinants of Water Demand Patterns

Interviews with GWCL revealed that economic growth is the main factor influencing demand for water in GAMA. Somewhere in the late 1990s, research by Mensah (1999), demonstrated that efforts were being made to turn Ghana into a middle-income country by the year 2020. To achieve this, the economy must grow at an average rate of 8% per annum. By November 2010, this status was achieved (World Bank, 2011). The World Bank projected in January 2011 that Ghana would be the fastest growing economy in sub-Saharan Africa with a growth rate of 13.4% in 2011, dropping to 10% in 2012. Inherent in this economic growth is population increase. The increase in population is influenced by migration from other regions and natural increase. Currently, the rate of population growth is 2.8% in the GAMA, which is even higher than the national rate of 2.4% and more than 50% of this rate is attributed to migration (PHC, 2010). This growth influence the lifestyle of individuals consequently affecting social goods like water provision which is seen in the industrial, agricultural and domestic sectors of the economy. GWCL anticipates that in future, economic growth will still be a major determinant, influencing demand for water, especially as Ghana has become a lower middle-income country.

The ⁵Table 4.2 shows consumption of water in domestic and non-domestic areas of GAMA prepared for GWCL, made up of Accra, Tema and Ga districts. From the table, consumption was highest in Accra, followed by Tema and Ga, respectively. In Accra, it was 45.1mil m³ (million cubic metres) in 1995, increased through to 90.4mil m³ in 2005 and expected to reach 62.8mil m³ by 2015. However, lower figures were recorded in Ga districts in the years 1995, 2005 and the projected 2015 to include 4.2mil m³, 8.6mil m³, and 17.4mil m³. In sum, the quantities of water

⁵ All figures are in millions;
1 m³ is approximately equal to 1000litres

needed to cover the needs of both the populations and economic activity will increase from 177,000m³ per day to 422,000m³ per day, between 1995 to 2015 and unless there is a boom in economic development, demographic growth will have the strongest influence on the evolution of water consumption.

Table 4. 2: Trends of Water Consumption in ATMA per Type of Consumer and per District - (in millions of m³)

Type of Consumer	Accra	Tema	Ga	Total mil m ³	Total (m ³ per day)
1995					
Domestic	33.0	8.4	3.3	44.7	122,500
Non Domestic	12.1	7.0	0.9	20.0	55,000
Total	45.1	15.4	4.2	64.7	177,500
Domestic Connections	67,580	31,502	4,794	103,875	177,500
2005					
Domestic	46.5	14.6	6.4	67.5	185.00
Non-Domestic	16.3	10.9	2.2	29.4	80,500
Total	62.8	25.5	8.6	96.9	265,500
Domestic Connections	105,983	56,884	19,217	182,083	
2015					
Domestic	67.8	29.0	13.4	110.2	302,000
Non-Domestic	22.6	17.1	4.0	43.7	120,000
Total	90.4	46.1	17.4	153.9	422,000
Domestic Connections	170,393	111,681	56,963	339,037	

Source: OTUI Report (2009)

Further, the report revealed that, domestic consumption would continue to grow the fastest, reaching an average of 4.6% per year, caused by heavy demographic pressures and non-domestic consumption will increase at a slower rate of 4.0% per year on average.

4.3.2 Spatial Variation in Water Demand Patterns

Several proposals have been made about the minimum standard of water use per person worldwide.

According to Lamptey, (2010), it is difficult to estimate the amount of water needed to maintain

acceptable or minimum living standards. WHO advocates for 20 l/c/d. Gleick (1998) proposes that international organizations and water providers adopt an overall basic water requirement of 50 litres per person per day, as a minimum standard to meet four basic needs of drinking, sanitation, bathing, and cooking. Again, a range of 20 to 40 litres of freshwater per person per day is generally considered to be a necessary minimum to meet needs for drinking and sanitation alone (Gleick, 1998). Moreover, different countries use different figures for total water consumption.

According to several researchers, factors influencing these standard derivations include occupancy and household income. They however review that these factors are unstable and very difficult to measure. The most practicable basis for estimation of domestic consumption analyzed by Twort *et al.*, (2000) include class of dwelling occupied in terms of type (flat or house), and value (size, age) since it permits visual identification of the facility. Others also combine population density and class of the area (Lamprey, 2010). From discussions with GWCL however, they made use of the income status, their geographical location and the density of people living in an area to estimate the standard. They also factored in industrial use of water into the per-capita consumption of an individual since they did not have a standard way of measuring industrial water use. So their average working value of 120-140l/c/d is based primarily on the factors mentioned above.

Physical and human factors were identified during the fieldwork to play significant roles in influencing the spatial variation or uneven water supply. Concerning the physical factors, emphasis is placed on the pressure of water in the GWCL-Accra supply system, hence the distribution of potable water in Accra is uneven leading to the classification of supply areas into pressure zones, based on topographical variations of high, medium and low pressure zones. Others include insufficient booster stations and air valves, leakages, bursts, power surges, outages, and insufficient production of water to meet demand.

Central to the human factors, there is variability in water distributed to the different communities and factors influencing these may include social class, social amenities like hospitals, markets, schools and the form of housing (compound, estate, flats and gated communities). It was also recorded that, another human factor was the rapid and uncoordinated development of residential facilities (Songsore et al, 2005) without adequate planning with GWCL, which has contributed significantly to the worsening water situation in GAMA. A typical example is Ashale Botwe, which is a peri-urban community without adequate water infrastructure. Because of its close proximity to planned areas like East Legon, now compete for social amenities like water. Some of the water meant for East Legon is therefore diverted to Ashale Botwe thus compromising supply to the former, which hitherto received near normal supply, eventually resulting in rationed water distribution in the entire region.

4.3.3 Consumer Satisfaction with Potable Water Supply

Provision of water services by GWCL over the years has come under a barrage of criticisms. The findings of this study are not different from the public outcry. Even though the sampling sites used for this study have unequal access to potable water supply, generally respondents across these study sites expressed dissatisfaction with the services with the exception of Dansoman Estates (Table 4.3).

For the entire study areas, more than half-representing 53.3% expressed total dissatisfaction with the service provided. Another 10.8% were not emphatic about their response, though they did not like the service. However, 21.7% were very emphatic in their satisfaction with the service, most of who were found in Dansoman Estates. About 12 % responses showed some minimum level of satisfaction. Further, 1.7% could not share their opinions and 0.4% was neutral in their level of satisfaction.

At the community level, further analysis was done to distinguish the variations among the study localities. Respondents in Teshie and Ashale Botwe expressed total dissatisfaction with the service representing 77% and 90% respectively, whilst majority of respondents in Dansoman Estates (60%) were comfortable with the service. In East Legon, the level of satisfaction was variable (Table 4.3).

Table 4. 3: Community Satisfaction with the Level of Service by GWCL

Locality	Yes, Definitely	Yes, Perhaps	Neutral	No, Not Really	No Definitely	Don't Know	Total
East Legon	20%	15%	0%	20%	42%	3%	100%
Dansoman Estates	60%	27%	2%	7%	5%	0%	100%
Teshie	7%	7%	0%	10%	77%	0%	100%
Ashale Botwe	0%	0%	0%	7%	90%	0%	100%

$X^2=1.424$

P-value: 0.000***

*** indicates significant at $p < 0.01$
Fieldwork, 2011

Responses based on gender were not significantly different as respondents in the male and female categories expressed similar dislike for the service (53% and 54%, Table 4.4). Fewer percentages were also recorded for those who liked the service; 24% for the males and 20% for the females.

Table 4. 4: Level of Satisfaction with GWCL Service regarding Gender

	Yes, Definitely	Yes, Perhaps	Neutral	No, Not Really	No Definitely	Don't Know	TOTAL
Male	24%	14%	0%	5%	53%	2%	100%
Female	20%	11%	0%	15%	54%	1%	100%

$X^2 = 7.887$

P-value: 0.163

Fieldwork, 2011

These findings conclusively demonstrate the low level of satisfaction with the services provided by the water company, which is consistent with the works of Awuah, 2007, and Kessie 2007. Significantly, the study went further to probe why consumers expressed such grave dissatisfaction with water provision (Figure 4.1).

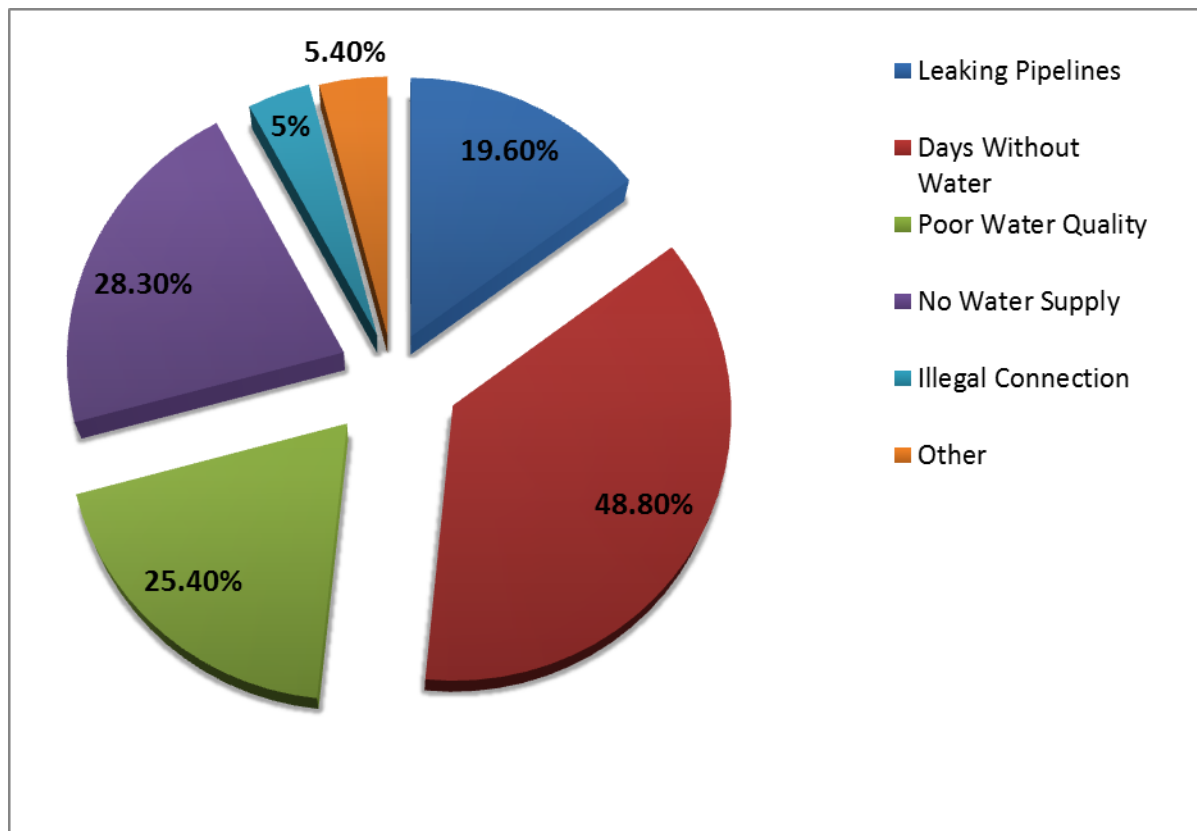


Figure 4. 1: Domestic Problems of Water Supply within GAMA (Multiple Responses)

Source: Fieldwork, 2011

Figure 4.1 shows multiple responses on reasons ascribed to the dissatisfaction with GWCL service to include leaking pipes, days without water, poor water quality, no water supply, illegal connection and ‘other’ like poor customer care. In all, 48.8% of all responses indicated days without water as their utmost reason, 28.3% attributed it to no water supply and another 25.4% were concerned about the quality of the water, leaking pipes (19.6%) and illegal connection (5%) in descending order of importance.

In addition, respondents were also asked to express their opinion on the problems facing the GWCL that did not allow for good service provision. These were put into gradations of causes; major, minor, not a cause and do not know. Table 4.5 provides a summary of the results. Notably, more than half of respondents identified the problem of fast expansion of township (58.8%), followed closely by frequently broken down pipelines (56.2%) and unplanned township (54.6%) as major problems facing the Company. Others like electric power outage and lack of technical expertise of GWCL staff to handle the pipe network were mainly found among the minor causes.

Table 4. 5: Attributable Problems of Water Supply

PROBLEM	Major cause	Minor cause	Not a cause	Don't Know	Total
Illegal connections	40%	31.9%	9.3%	18.8%	100%
GWCL lack technical expertise to handle the pipe network	42.1%	34.5%	9.6%	13.8%	100%
Tanker owners arrange with the GWCL staff to limit water supply	41.7%	25.3%	18.8%	14.2%	100%
Frequently broken down pipe lines	56.2%	22.6%	11.2%	10%	100%
Inadequate pipe lines to support fast expansion of township	58.8%	27.5%	5.8%	7.9%	100%
Unplanned township/community	54.6%	32.9%	5.8%	6.7%	100%

Electric power outage and surges	25.4%	42.5%	15.4%	16.7%	100%
Other	4.6%	0.00%	0.00%	95.4%	100%

Source: Field Work, 2011

From the interviews, the low level of satisfaction expressed by consumers makes consumers apprehensive to proposals for the increase in tariffs demanded by the Public Utility Regulatory Commission (PURC, 2011). On the other hand, when asked if they will be willing to pay more if the services were improved, half responded in the affirmative, whilst the other half were of the opinion that the problems of GWCL has come to stay if major structural changes are not carried out. These views cut across respondents in the high, middle and low-income areas.

4.4 Water Supply Patterns

Owing to increase in urban population without a corresponding increase in its infrastructure, the gap created between water supply and demand is widening. The breakdown of obsolete equipment, infrastructure and power interruptions is also worsening the situation. For example, from Figure 4.2, water supply from 2010 to 2012 did not see any increase in production (401,095; 400,297; 402,597) m³/day whilst the demand from its consumers kept increasing (575,660; 606,170; 636,997) m³/day for the same period (Figure 4.2). The demand according to GWCL put a lot of pressure on the already stressed water resources resulting in inferior water quality (Pers. Comm. GWCL, 2011).

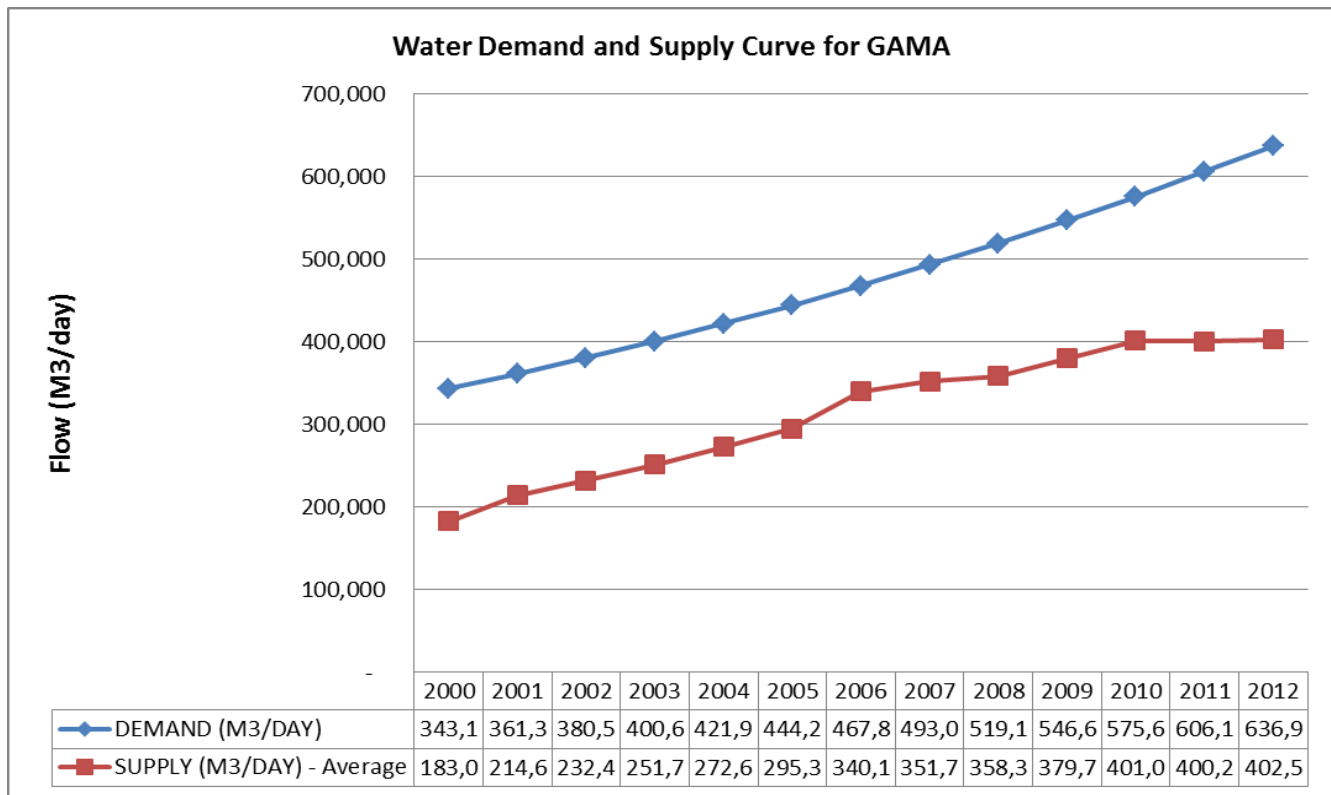


Figure 4. 2: Water Supply and Demand Curve for GAMA

Source: GWCL Planning Data, 2013

Loss of water produced through theft and leakages was also recorded. This is what is called non-revenue water. Non-Revenue Water (NRW) or Unaccounted for Water is the measure of water produced by GWCL, which is not translated into revenue due to water used for treatment and losses as a result of leakages and theft (PURC, 2009). As can be seen in the Table 4.6, the NRW was averaged at 40% from 2000 to 2007 then 2012 to 2014 and is expected to reduce to 25% by 2020 through some supply interventions implemented by GWCL. From 2008 to 2009, it rose from 50.1% to 51.6%. This was against a target of less than 30% set by the PURC. According to PURC (2009), efforts to keep up to a minimum target has not been successful over the years. In countries like

Denmark, Germany, Japan and Singapore, it is as low as 6%, 7%, 7% and 5% respectively. It can get as high as 70% in parts of Nigeria, 51% in Mexico, 26% in France, and 34% in Chile (Benouahi and Satoru, 2009).

Table 4. 6: Non-Revenue Water (NRW) for 2000 to 2020

Year	2000	2007	2008	2009	2012	2013	2014	2015	2016	2017	2019	2020
Non-Revenue Water %	40	40	50.1	51.6	40	40	40	35	35	35	30	25

Source, GWCL, 2012

For the supply system to work effectively and efficiently and to overcome the present water crisis, efforts are being made by GWCL to bridge the supply and demand gap through several interventions. Figure 4.3 shows planned supply intervention for GAMA until 2030. According to the graph, the water situation has worsened over the years from 2000 and it is expected to continue until 2014 (Figure 4.3). However, by 2015, the gap is expected to cross-over, resulting in increased supply and reduction in demand through interventions like increased supply, rainwater harvesting, reuse culture and efficient use of potable water (Pers. com GWCL, 2012). Owing to population pressures, which are expected to outpace development, the supply intervention will be short-lived by 2020 through to 2030, if newer measures are not implemented.

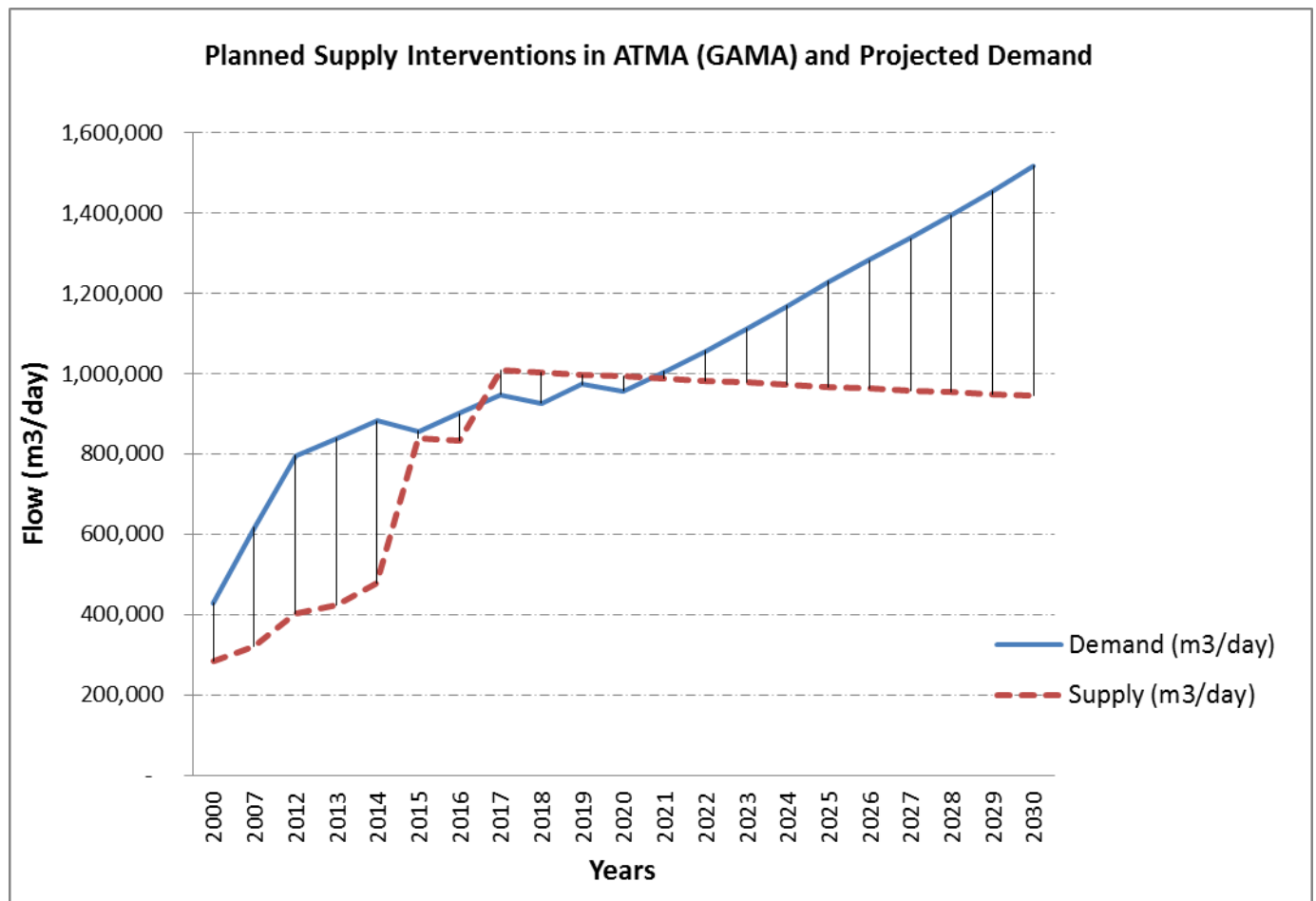


Figure 4. 3: Planned Supply Intervention for ATMA (GAMA)

Source: GWCL Planning Data, 2012

Today, owing to the shortfall in water supply, customer satisfaction ranges from excellent to very poor, depending on location of the customer. In the course of balancing demand and supply, GWCL has embarked on rationing programmes, which is negatively affecting socio-economic growth.

Appendix 3 shows the rationing map schedule of water in the GAMA. The pattern ranges from one day of water supply per week, to seven days per week. The poorly served areas like Teshie, Nungua, Madina, Adenta, Ashongman and East Legon residential areas receive water one day

per week, whereas those receiving seven days include Airport City, Ridge, Adabraka, La Bawaleshie and Dansoman (Appendices 1 and 2). Others, like South Labadi Estates, Baatsonaa, and Adjirigano⁶⁹ receive water 2, 3 and 5 days in a week, respectively. Ashale Botwe, however, receives water every other week. From the schedule, some consumers receive the water 12 hours and not the 24 hours, as per most scheduled areas. There is therefore an uneven pattern of water supply over the entire GAMA which is empirically supported by the rationing schedule (Appendix 3). The unevenness of this pattern is influenced significantly by the hydraulic dynamics in the pipe network (GWCL, 2011). Generally, the rationing schedule is done to ensure equitable distribution of water to urban areas.

Further, focusing on the infrastructure component, the GWCL water network has three main components. These are i) head works ii) transmission and iii) distribution. At each point, many factors inhibit flow pattern thereby affecting changes in supply. These factors will be the focus of the next section. Analysis of the supply patterns was based on in-depth interviews with officials of GWCL, PURC and WRC. Data from the household questionnaire survey was also used to balance claims from these institutions.

4.4.1 Factors Influencing Supply Patterns

The factors influencing water supply to users are vital for the effective management and planning in developed and developing countries (Chigumira and Mujere, 2007; Breslin, 2010). Supply of water to Accra is via three main sources, Kpong Head Works, Weija Head Works and Dodowa Well-fields. Water flow from the final water reservoir at Kpong is pumped to Tema booster station using electricity, whilst from Weija, water descends by gravity into the transmission system of the metropolitan area. Weija distribution covers more than 50% of GAMA. Since

Weija head works are supplied by gravity; distance thus affects its catchment, resulting in reduced pressure as water is transported. As a result, a number of booster stations have been strategically located to ensure continuity of water to consumers. A third source, boreholes were commissioned at Dodowa-Oyibi to supply water up to a capacity of 3 million gallons per day to parts of Madina and Adenta, which is also not adequate.

The rationing programme (Appendix 3) is another challenge, which is having several setbacks due to the following factors that alter the pattern. These have been identified by GWCL to include: topography, power interruptions, density of pipe network, pipe bursts, and technical challenges which include *planned or unplanned maintenance, duration of maintenance, turnkey operators, faulty valves and air in piped system.*

GWCL further notes that, the topography of Accra is undulating and this is one of the key factors responsible for three levels of pressure zones; High Pressure Zone (HPZ), Medium Pressure Zone (MPZ) and Low Pressure Zone (LPZ) (Figure 4.4). Accordingly, some minimal pressure level is required to allow water to flow adequately in pipes. So depending on one's location, one is challenged or advantaged. The inability to have this minimal pressure at all locations, due to variations in elevation results in the definition of the three pressure zones. Consequently, a number of booster stations have been located at the LPZ to ensure a boosting of water to the HPZ. The LPZ covers areas with theoretical ground elevation from 0 - 30.5 m above sea level. This is by far the most extensive pressure zone, since it covers the entire sector of the Odaw River and nearly the entire city centre, i.e. the Accra Inner Ring. It covers the lowest area of Accra in the West, the South, and the East and partially in the North of the city (SIP, 2011).

The Medium Pressure Zone covers areas with theoretical ground elevation between 30.5m - 61m, normally controlled by MPZ Reservoir. The Medium Pressure Zone covers the Eastern part of Accra, located south of the Alajo River, a tributary of the Odaw River, whose course travels upstream from the Alajo sector towards Tetteh Quarshie Circle. The Eastern limit of the MPZ is the Kpeshie Lagoon. This zone includes the following sectors: Nima, Kanda, West Ridge and East Ridge, Airport Residential Area, Cantonments, North Labone, Burma Camp and Labadi. It reaches into the Inner Circle at North Ridge on both sides of the Independence Avenue.

The High Pressure Zone covers areas with theoretical ground elevation above 61 m controlled by HPZ Reservoir. The High Pressure Zone is located north of the Accra-Tema Motorway. It encompasses the sectors of Legon, Achimota, Ghana Atomic Energy Commission and Madina and reaches north along the Adenta Road to Oyarifa (SIP, 2011). The Tema distribution system has one pressure zone supplied from Tema Terminal Reservoir. Water is conveyed to the town by a 1,050 mm diameter steel main laid in 1965 and directly connected to the Distribution Network (SIP, 2011).

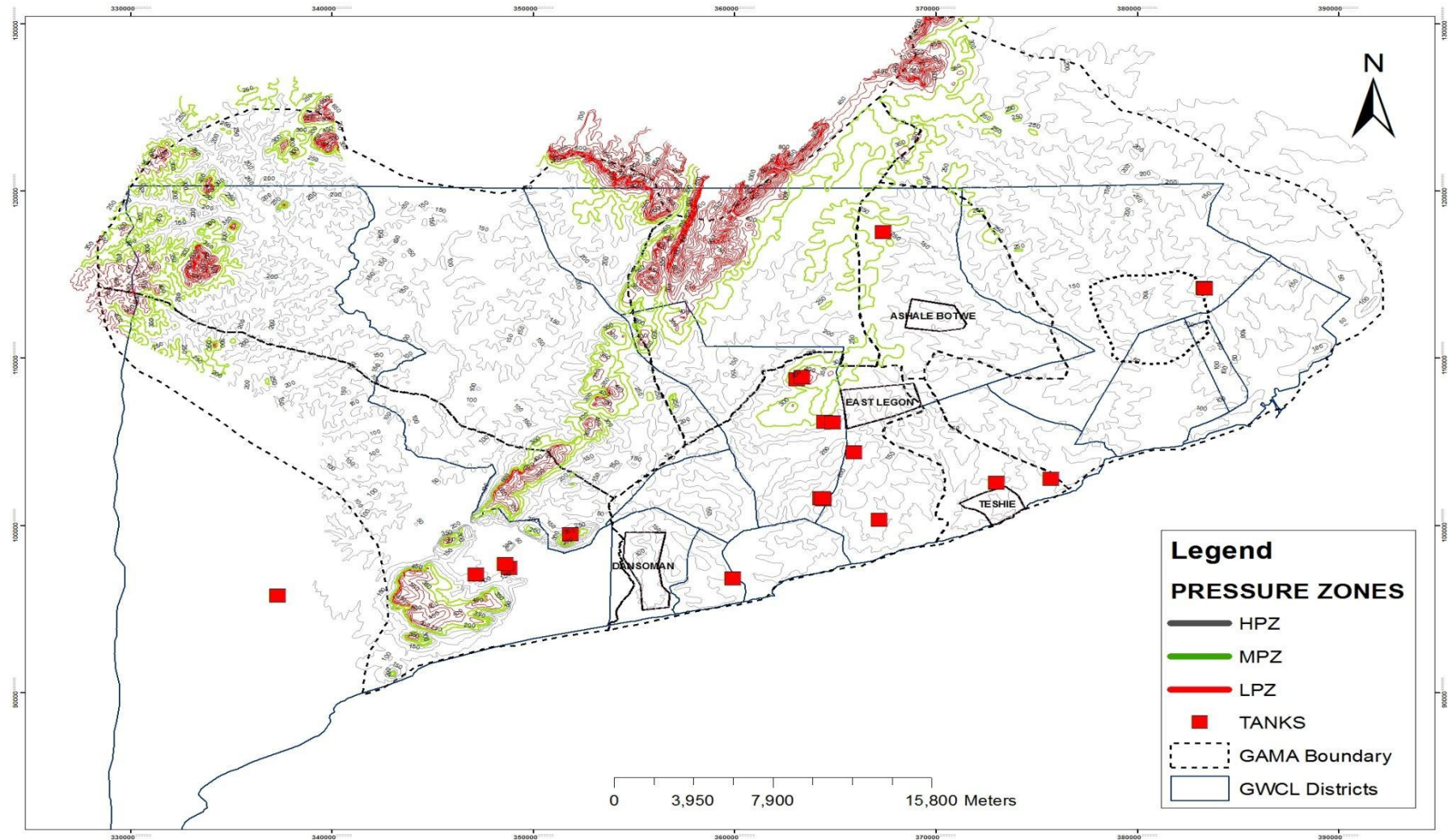


Figure 4. 4: Contour Map of Study Area Showing Pressure Zones and Tanks

Source: GWCL, 2011; Fieldwork, 2011

A vast central area, lying between Tema and Accra, is not directly supplied by a specific system. This area is presently supplied from both Accra Network, through different Pressure Zone Pipes, and Tema Reservoir, through the Teshie-Nungua gravity line and through some direct connection on the pressure main to Accra (SIP, 2011). From Figure 4.4, Dansoman is in a MPZ, but boosted. A significant part of Teshie is in HPZ, whilst the rest is by gravity lines. Ashale Botwe and East Legon are in HPZ. Nevertheless, the pressure zones on the ground do not entirely conform to the water situation in the localities, hence the evaluation of other determinants affecting water supply described below.

Consistent with Savenije and van der Zaag (2002), the issue of maintenance has been identified as a major challenge to the supply of water. This can be linked closely to the price of water. If water is free, then the water provider does not receive sufficient payment for its services. Consequently, the provider is not able to maintain the system adequately, and, hence, the quality of services deteriorates (Rogers et al. 1997; Savenije and van der Zaag, 2002).

According to in-depth interviews with GWCL officials, the cost of producing water from Kpong is about double the cost from Weija. This cost is reflected in the hydroelectric power (HEP) used to pump water from Kpong to Accra, as against the cost of chemicals required to treat water at Weija. Even though Weija is heavily polluted and requires large quantities of chemicals at very high costs for treating the water, this cost is lower than the amount required from HEP generation to pump the water from Kpong to Accra, due to the long distance. They therefore advocate that if measures are taken to ensure the protection and maintenance of the water resource at Weija, the cost of water production and distribution will be manageable which will ultimately affect its price or cost.

Other two concerns on maintenance gathered from the in-depth interview relate to planned or unplanned maintenance. These comprise water pumps servicing, pump breakdowns, faulty valves and power transformer breakdowns. This can impact greatly on flow patterns, especially if breakdowns are spontaneous and habitual, reducing the quality of service. There is also the issue of duration of maintenance (*down-time*), that is, the number of hours the plant is shut down. Longer down-time drains all water from the transmission mains rendering the service lines also dry. Transmission mains are the main pipe network from production points, Kpong and Weija headworks and service lines are the auxiliary pipe network from the transmission mains to consumers (GWCL, 2011). When this happens, it can take the whole transmission mains a couple of days to *fill* with water for the supply of water to normalize. According to GWCL, this process, in the worst scenario can last seven days.

Turnkey operation is another maintenance issue. It works with a principle of throttle valves or water valves located at specific points on the transmission mains. If water passing through these mains is too much or too little, these valves are designed to redirect water flow to other areas, thus regulating flow. They have the advantage of regulating flow accurately, but ultimately influencing water distribution to localities. Plate 4.1 shows some of the types of valves found in the study area.

Plate 4. 1: Tap-Water Throttle Valves and a Domestic Water Meter



Source: Fieldwork, 2011

Pipeline burst is one of the biggest challenges of water supply, both to the distributor and the consumer. This, according to management of GWCL, is problematic, particularly when logistics is not readily available to address the issue. According to the management, an example was particularly seen at the Kpong head works, where a major pipe burst lasted for thirty days, because an expertise from overseas was required. Pipe-line bursts and leakages are common in GAMA because most of the pipes have not been replaced since the 1950s and are either damaged, or in a bad condition, hence large volumes of water are lost before reaching consumers (SIP, 2011).

Table 4.8 shows a downward, but still high trend (8,806; 8,707; 8,707; and 4,590) of pipe bursts in the study area. The low figures for 2010, according to PURC are due to phone-in measures put in place to report bursts as they occur for rapid response units to salvage the infrastructure.

Table 4. 7: Leakages and Pipe Bursts within Accra- Tema Metropolitan Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (#)
2007	712	719	669	752	841	790	770	848	944	945	816	-	8,806
2008	829	728	792	228	796	168	988	829	777	789	822	961	8,707
2009	910	754	140	499	551	600	426	721	611	407	366	432	8,707
2010	268	516	322	525	880	853	-	-	396	482	100	248	4,590

Source: GWCL, 2011

Another major distinctive feature of supply pattern is the layout of the pipe network system. The layout in terms of quantity and pipe-width (Figure 4.5) as well as the point at which water is tapped on the distribution main greatly affect the amount of water reaching consumers. The interviews confirmed that, the denser the network, the better the areas served. If on the other hand, the network is sparse (as found in Teshie and Ashale Botwe), it influences the water pressure and consumers at the end of the network are not covered, most of the time.

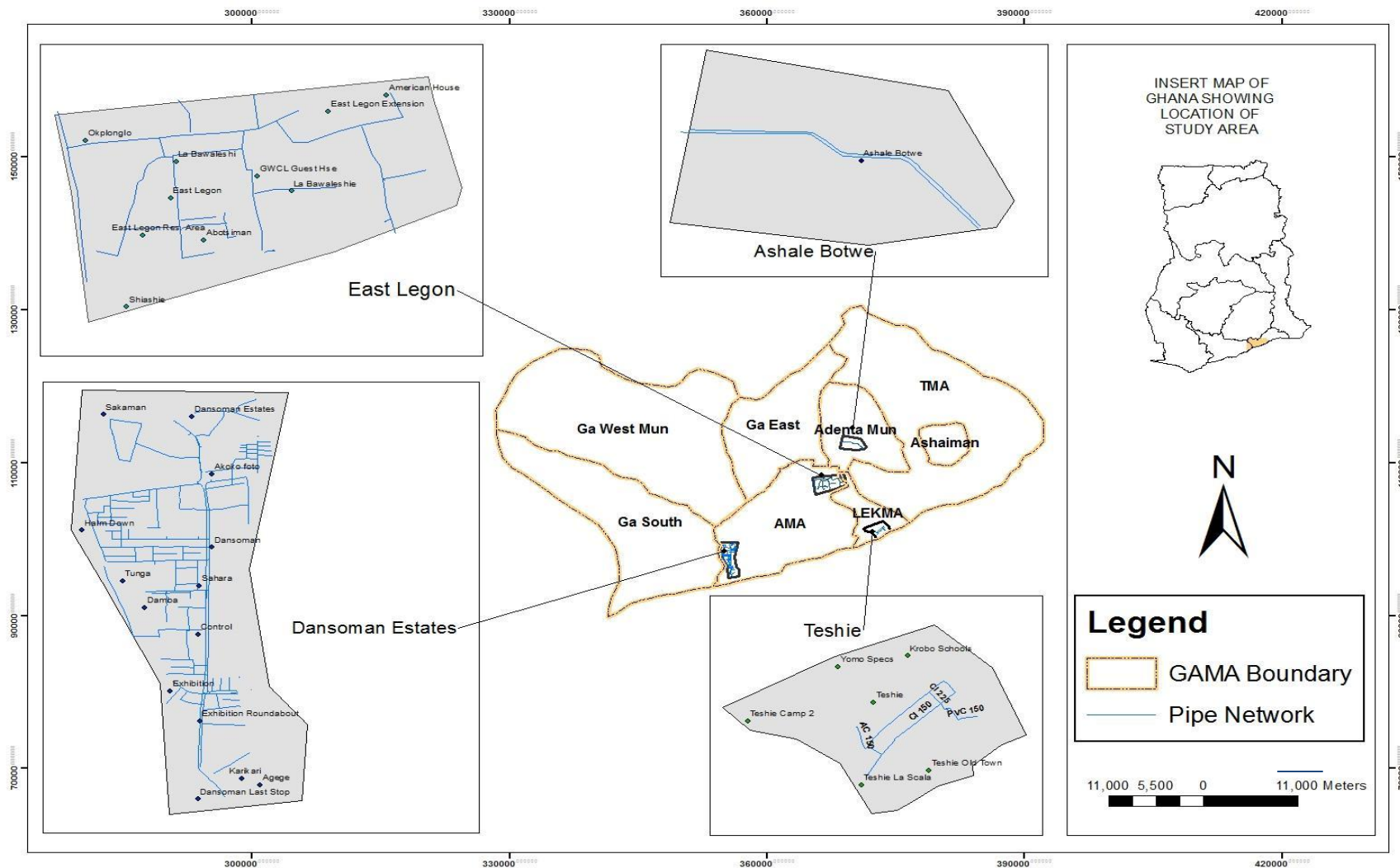


Figure 4. 5: Map of GAMA, Showing Density of Pipe Network in Sampled Localities

Source: GWCL, 2010

From Figure 4.5, it is observed that more pipes were laid at Dansoman than any of the other study localities, hence good water supply. Ashale Botwe and Teshie had the least number of pipes, hence poor water supply, while East Legon fell in-between, with pipe layout only at certain locations. This observation in East Legon and Teshie was in line with residents' outcry during the field survey on the number of times they get water flowing through their taps, which was 1-2 times per week. However, the field response for Ashale Botwe (Figure 4.7) showed marked contrast with GWCL rationing map (Figure 4.6). As can be seen, the graph (based on field responses) showed no supply, whilst the map (GWCL rationing map) indicated twice every other week. This was partly due to localized factors like insufficient pipe layouts, leakages and pipe bursts, power surges, topographical variations and insufficient booster stations and air valves.

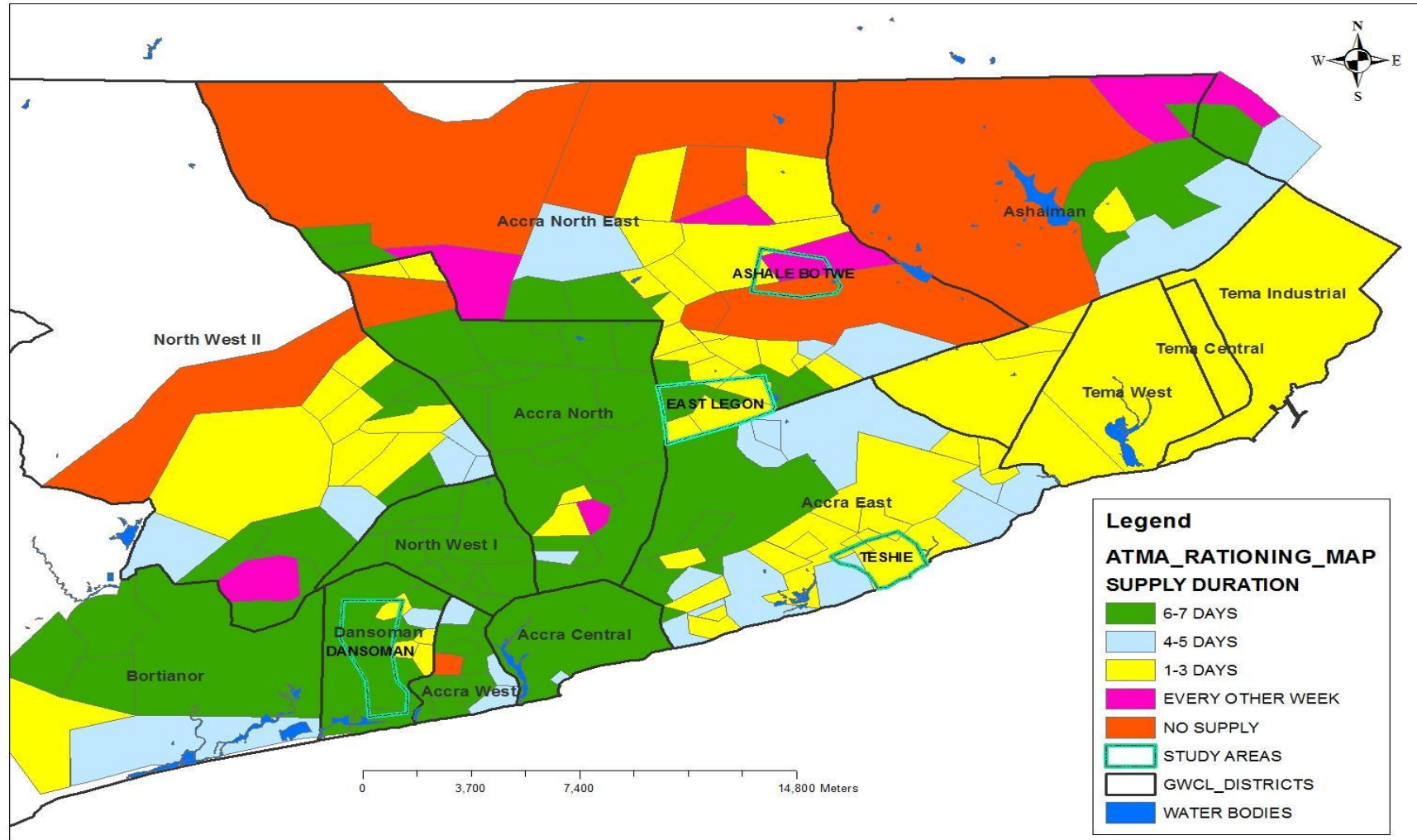


Figure 4. 6: GWCL Rationing Map of ATMA (GAMA)

Source: GWCL-GIS Section, 2011

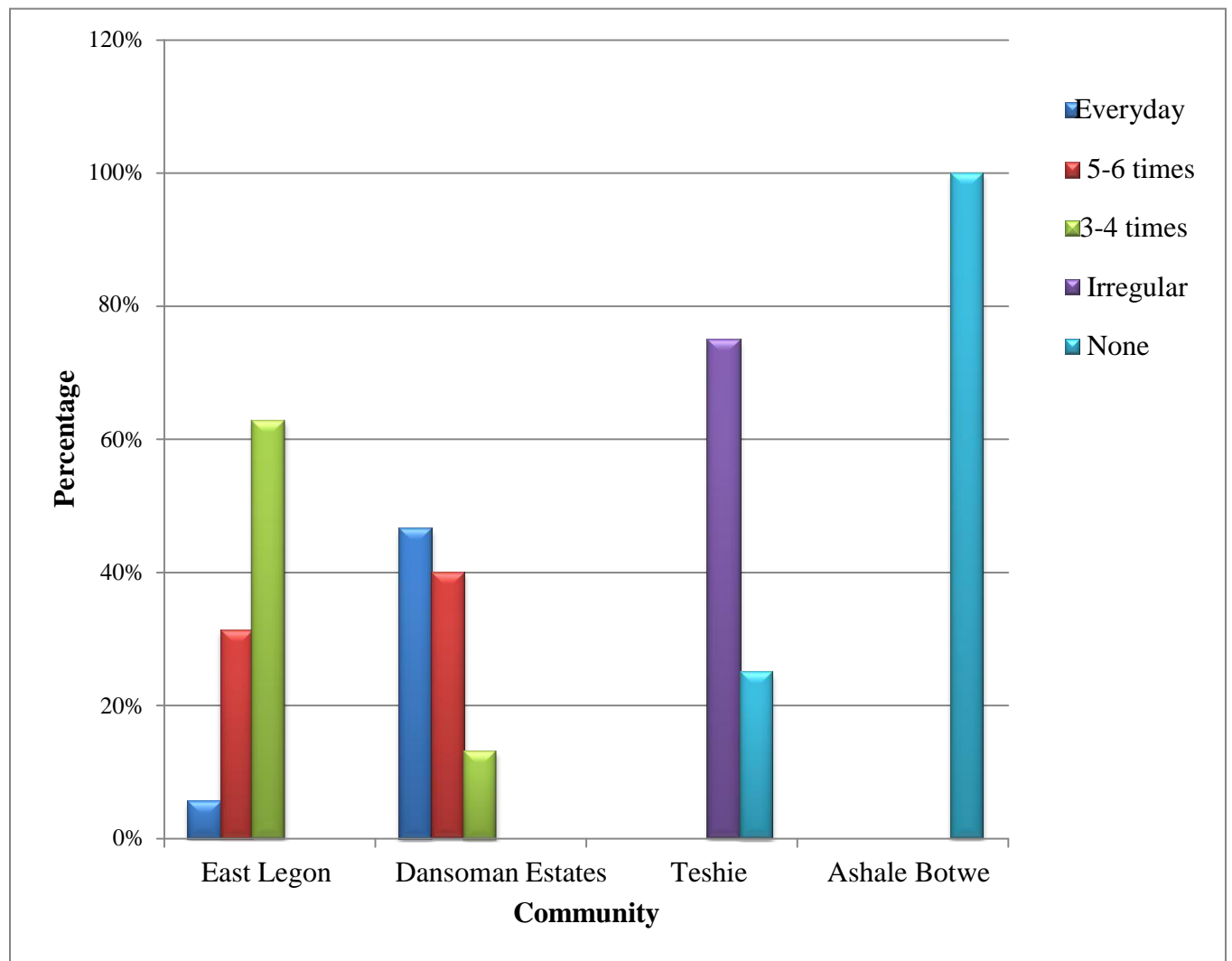


Figure 4. 7: Field Responses Showing Rationing Schedules in GAMA

Source: Fieldwork, 2011

Further interviewing of respondents showed variations in water availability at points along which they were connected on the *service lines*. Since the service lines are hardly fully filled (Pers. Comm. GWCL, 2011), there is unequal supply to households, especially since tapping points are not uniform, and some receive water twice a week, others, thrice a week, and yet still others, all seven days in the same locality. Residents who tapped on top of transmission mains suffered

the highest variability in times of irregular water flow from GWCL. Water was most available where connections were made from the bottom or side of the service lines.

Another finding was that, some residents in East Legon avoided the rationing by tapping illegally into multiple pipe networks so that they could have constant water supply. For example, it was common to find one house on a row of houses in East Legon receiving water supply six times in a week while the others receive twice in a week, and the rationing plan indicated twice a week.

Low-income areas, such as Teshie, could not afford to tap into many lines, hence their inability to enjoy the extra water supply. This appeared to be correlated with wealth. Ashale Botwe, a peri-urban fringe and developing community, did not follow the rationing schedule because of fewer pipe networks, due to unplanned developments and GWCL inability to match pipe infrastructure with population growth of the area.

4.4.2 Uneven Water Supply Coverage

This section highlights the unevenness of supply coverage in Ashale Botwe, Dansoman Estates, East Legon and Teshie, focusing on water as it affects income classes. High-income areas usually house the affluent and politicians in society (Savenije and van der Zang, 2002). Such areas have more water and other resource using amenities. Where these are not available, they tend to use their power to acquire them. This is to the detriment of low-income areas. Eventually the system collapses, and where the poor use inferior resources like unsafe water, or pay excessive amounts of money to water vendors, while wealthy and influential people receive piped water directly into their houses, at subsidized rates. Thus, according to Savenije and van der Zang (2002), the water-for-free policy, often results in powerful and rich people getting water cheaply, while poor people buy water at excessive rates or drink unsafe water. The above situation is seen in the availability and use of more water-

demanding facilities such as washing machines, dishwashers, swimming pools, and vast lawns requiring several cubic metres for watering in high income areas, affecting general water distribution and coverage (Figure 4.8). If, however, there is a general challenge of supply from head works, all areas are affected, irrespective of class.

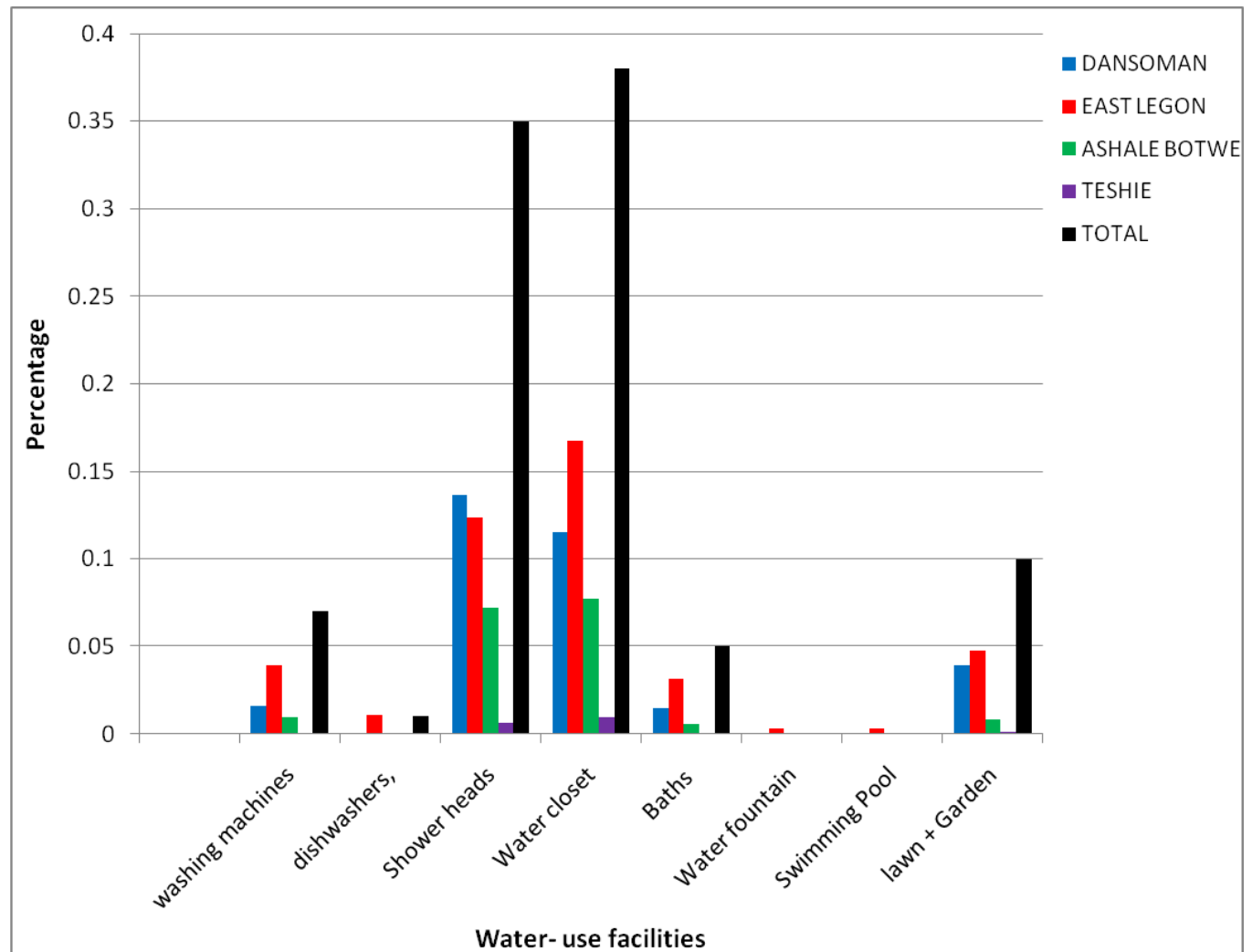


Figure 4. 8: Water Use and Demanding Facilities in the Sampled Localities

⁶Source: Fieldwork, 2011

⁶ Some facilities like water closets were multiple in some households in East Legon and Dansoman Estates

To explain quantity of water-use in the study localities, Figure 4.9 shows residents in each of the localities who were questioned on the quantity of water used per person per day. Water used by all respondents ranged from 50 l/c/d to 400 l/c/d. Of significant importance were the high water use of 400l/c/d that was recorded only in East Legon and Dansoman Estates. This finding was clearly attributed to wealth and good water supply in the two localities respectively. From figure 4.9, Residents in East Legon, Dansoman Estates and Teshie mostly used water in the 100-200l/c/d category followed by 50-100l/c/d, whilst Ashale Botwe, because of their limited water availability recorded water use of 50-100l/c/d followed by 100-200l/c/d and 200-300l/c/d respectively.

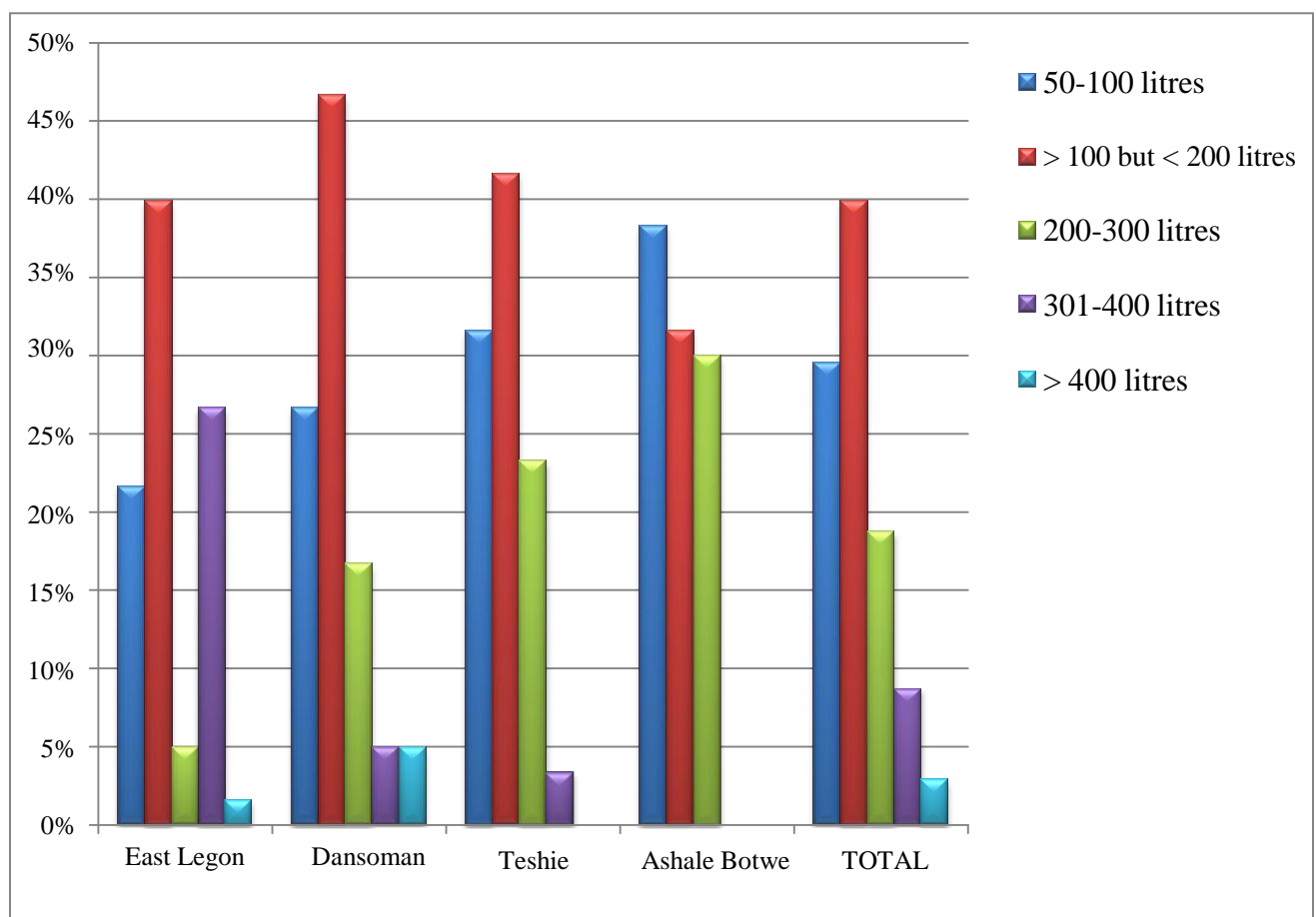


Figure 4. 9: Estimate of Pipe Water Used by Household per Each Sub Locality

Source: Fieldwork, 2011

Uneven supply was also influenced by people living in the location of certain social amenities like schools, hospitals, hotels, airport and industries. Some of these areas, according to GWCL receive constant water supply. Notable among them are Ministries, Okaishie, Central Business District of Accra, the Christianborg Castle, and Motorway extension, so, consumers living in such areas are categorized as living in areas categorized by GWCL as ‘important’. Others, who do not live in such areas, follow the rationing schedule.

4.4.3 Changing Trends of Supply Coverage

Most urban researches in Ghana have confirmed that Accra is growing at a rate far in excess of the expansion of its utilities (Awuah, 2007; Songsore, 2008; Dovie, 2009; Adank, 2011). Provisional report of the 2010 PHC puts Accra’s population at about 4 million, representing an increase of about 1million inhabitants (33.33%) from 3 million in 2000. Further, the transient population in Accra also stands at about 1.3million people (PHC, 2010), hence the need for an increase in water coverage. New communities are springing up in many parts of GAMA, but without a commensurate increase in water supply from GWCL. Ashale Botwe is a classic example, where until recently, due to its rapid urbanization, there is a government focus on increasing their pipe network. During the fieldwork, observations were made about pipe layout in Ashale Botwe as part of the network expansion. This activity, “is long overdue”, according to residents of the area who say they have not seen water flow through their taps for the past 20 years, but they acknowledge it is still a step in the right direction.

Interviews with GWCL revealed that another changing trend of supply is the springing up of new industries in the fringe communities and industrial areas. Example, is the Ghana Free Zones

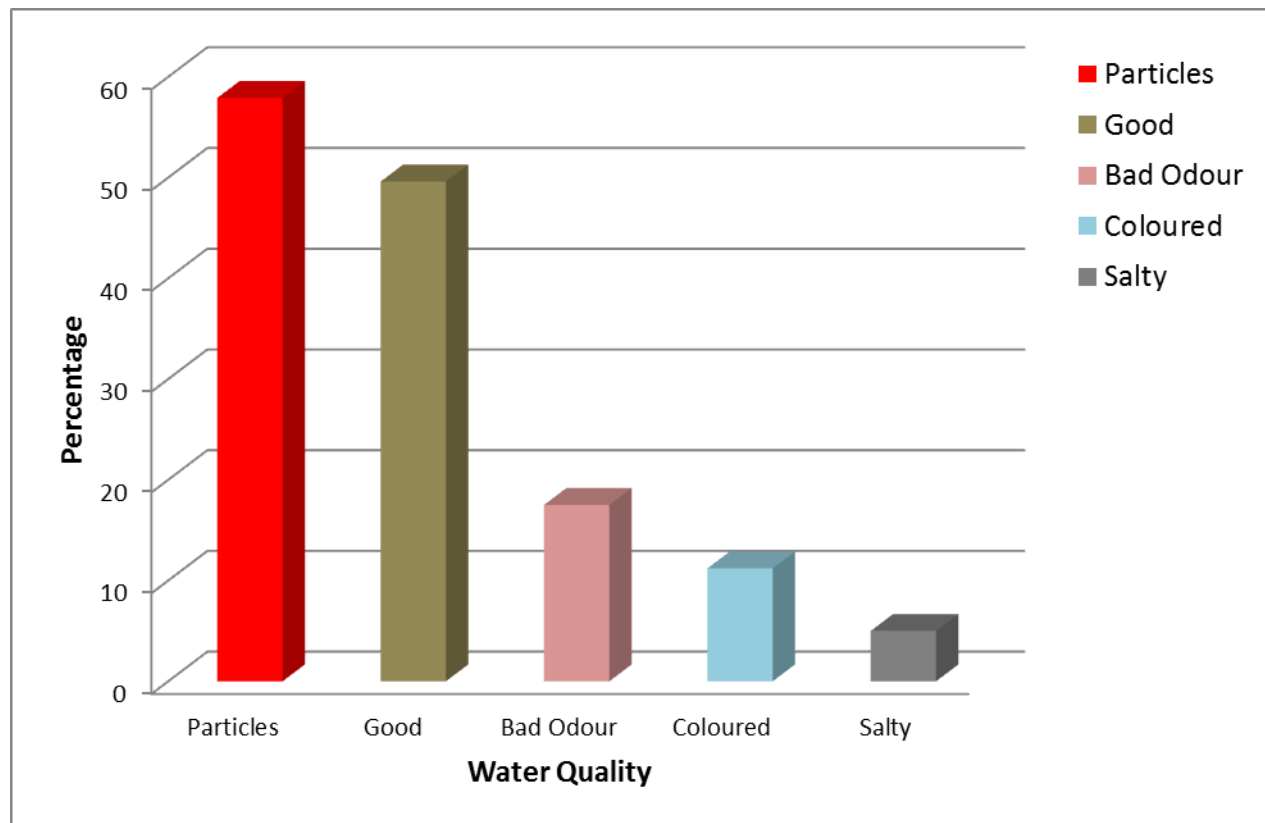
Belt on the Tema Motorway. These industries are fast approaching urban areas and vice versa, changing their core functions. This ultimately affects GWCL responsibility to such localities.

Sachet water producers, according to GWCL, are also a significant culprit to the changing pattern. For the past 3 years, they have increased production. They draw a lot of water meant for domestic consumption and redistribute to other areas, or even transport it over long distances to other regions of the country, such as Western and Volta Regions. This also ultimately creates pre-mature shortage of water in the GAMA.

4.4.4 Community Perception and Assessment of Quality of Potable Water

Survey research generally indicates that most people in countries with reliable supplies perceive tap water risks as small (e.g. Grondin et al., 1995; Grondin & Levallois, 1999). Perceptions of drinking water safety and risk seem to be consistent and tap water is generally regarded as safe (DWI, 1998; MORI, 2002; Songsore 2009). In recent times, this situation may be perceived as unstable and deteriorating (Slovic, 2000). Such decline of water quality may be due to a general inter-temporal pessimism (Hagerty, 2003). Very few studies have tried to discriminate which health risks are perceived to be associated with drinking water. An example of such studies is by Songsore et al. on “The State of Environmental Health of the GAMA in 2005” and “Environmental Health Watch and Disaster Monitoring in the GAMA in 2009”. In a Canadian survey, respondents identified gastrointestinal disorders, infectious diseases, cancer, contamination and intoxication as potential risks (Levallois et al., 1999). In GAMA, water supply from the Weija and Kpong head works have shown marked deterioration in quality due to anthropogenic activities, along the banks of the rivers. This renders water stored for a number of days unsafe for consumption, especially when the chlorine is believed to have worn off (pers. comm., GWCL, 2011).

This was the opinion of respondents whose views were sought on the quality of potable water and its associated risks. The quality was rated on gradations of good, particled, bad odour, coloured and salty. Using multiple responses, 57.9% of respondents held that it had particles inside. Another 49.6% said it was good. The rest, 17.5%, 11.2% and 5% said it had bad odour, was coloured and salty, respectively (Figure .10).



⁷Figure 4. 10: Perception of Water Quality among Respondents in GAMA

Source: Fieldwork, 2011

As a result, it has to be boiled, if consumers want to drink it, or they simply use it for purposes requiring heating of the water, like cooking. Their responses further gave the impression that they were generally not satisfied with the service provided by GWCL.

⁷ Multiple responses showing perception of water quality among respondents in GAMA

4.5 Chapter Summary

Chapter four attempted to look at the existing water demand and supply patterns in GAMA. It also investigated the performance of GWCL from perspective of the respondents and how they perceive the problem can be solved. From the analysis, demand for water is influenced by population increase and unless there is a boom in economic development, it will still be the single most important cause of water demand. Coupled with demand issues are supply problems on the side of the provider, GWCL. Issues of maintenance, lack of expertise, topographical challenges, inadequate infrastructure and inability of GWCL to meet and plan ahead of growing expansions of communities were some of the identified problems. In the course of balancing demand and supply, GWCL embarked on water rationing programmes, which according to respondents is not very effective hence need for a holistic approach in addressing their problems.

CHAPTER 5 COPING WITH INADEQUATE POTABLE WATER SUPPLY

5.1 Introduction

This Chapter provides information on the strategies that households with inadequate water supply adopt to cope with the stress. Households with no connections to potable water supply and those connected but experience frequent interruptions and periods without water supply are considered here. Almost all the households surveyed in Dansoman Estates were reported to have access to potable water continuously, whereas East Legon was heavily rationed with 2 to 4 days water supply in 2011/2012. Teshie had access to pipe water, but mostly through communal stand pipes, with very few households having direct connections, depending on their wealth. The area was also rationed to receive water 1-2 times in a week. On the other hand, none of the respondents surveyed in Ashale Botwe had access to tap water and had to resort to other modes of acquisition. How then do these different households with unequal access to water supply from GWCL cope with water stress? A number of supply adaptation measures and demand management measures form the focus of this chapter. The supply measures include rainwater use, borehole/well water use, wastewater reuse, tanker and vending services as well as neighbour water use. The management measures include judicious use of water and the use of water holding facilities to save cost and time in water acquisition. Analysis for the chapter was derived from focus group discussions and questionnaire survey.

5.2 Supply Adaptation Measures at the Household Level

The supply adaptation measures at the household level include strategies adopted by households to augment and/or to supplement existing and non-existing water supplies. These adaptation measures largely depend on the wealth of the sampled localities and their willingness to invest in other

sources. For example, according to Taylor et al (2002), the urban poor, as defined by the Living Standard Measurement, are the hardest hit by the shortage in water supply and hence, have to rely on neighbours and water vendors for their daily water supply, and end up paying about 20 times more than those connected to and served by the GWCL distribution network (Taylor et al, 2002). These adaptation measures were put under various sub groupings of borehole, rainwater, tanker, vendor, well and neighbour services. Table 5.1 shows the breakdown of the coping strategies in the four sampled localities.

Table 5. 1: Percentages of Households adopting Coping Strategies by Residential Areas

	East Legon	Dansoman Estates	Teshie	Ashale Botwe
Rain	21%	31%	33%	15%
Neighbour	33%	33%	17%	17%
Vendor	6%	13%	36%	45%
Tanker	29	6%	18%	47%
Borehole	32%	8%	5%	55%
Well	29%	6%	18%	47%

Source: Fieldwork, 2011

5.2.1 Boreholes and Wells

A well or borehole is a means of tapping into aquifer to gain access to groundwater. The difference according to ECP Group, (2008) is that, usually, a borehole is drilled by machine and is relatively small in diameter but deeper, whereas a well is usually sunk by hand (hand-dug), shallow and is relatively large in diameter. The importance of groundwater is easily overlooked. It is a hidden asset, out of sight and out of mind and yet for many communities it is their only source of water supply.

Generally, boreholes were not widespread in the study areas. Close to 16% of respondents used boreholes whereas 84.17% used other sources. For example, they were not common in Dansoman and Teshie, but were common in Ashale Botwe (35%) and East Legon (20%), which had households resorting to this form of adaptation measure. Dansoman and Teshie recorded 5% and 3.3% incidence of boreholes respectively (Table 5.2). Nevertheless, all respondents in the four sampled localities expressed preference for borehole water use to the other modes of access to water. Their main concern was the high cost of construction.

Table 5. 2: Borehole water use in the study communities

Community	Yes	No	Total
East Legon	12(20%)	48(80%)	60(100%)
Dansoman Estates	3(5%)	57(95%)	60(100%)
Teshie	2(3.3%)	58(96.7%)	60(100%)
Ashale Botwe	21(35%)	39(65%)	60(100%)

Source: Fieldwork, 2011

Table 5. 3: Well water use in the study communities

Community	Yes	No	Total
East Legon	2(3.33%)	58(96.67%)	60(100%)
Dansoman Estates	1(1.67%)	59(98.33%)	60(100%)
Teshie	34(56.67%)	26(43.33%)	60(100%)
Ashale Botwe	0(0.00%)	60(100%)	60(100%)

Source: Fieldwork, 2011

The hand dug wells were equally not common in the study areas (15.42%), except for Teshie, which recorded 34 (56.67%) shallow wells in the area (Table 5.3). This high figure was explained by the soft soils in the area and the fact that wells are shallow and can therefore be done with low budget. Further, these wells were also seen as an income generating activity, requiring little investment in the form of well owners engaging in selling water by the bucket. They, however, complained that the well water was usually salty, because of the town's closeness to the sea. As a result, they use the water for cleaning and other non-potable uses.

Generally, as expressed by respondents in Ashale Botwe, East Legon and Dansoman Estates, one important problem of borehole water use is the cost incurred in its construction. According to the group discussions, it is very expensive to construct but when completed, it can be a very cheap source of water. One respondent in East Legon had this to say;

“I spent about two thousand Ghana cedis in my borehole construction. I almost did not do it but was told by a friend that, if I am successful, it will be there forever so I resorted to and it is still serving me. I have not regretted it” (Madam Monah, April, 2011).

They further indicated that, the cost is seen in the drilling process to an appreciable depth whilst hoping that the water derived is not salty. Salty water is usually got because of the bedrock that is hit and the geographical location of the borehole (as found in Teshie). If salty water is experienced, an additional cost is incurred in a filtering process to a potable state. Filters range from simple models to sophisticated ones like *Reverse Osmosis System* (Plate 5.1) that filter the water to a potable state. Further, another cost issue expressed by respondents, was pumping the underground water to an overhead tank, a luxury most people do not resort to, especially when hydroelectric power was required.

Plate 5. 1: Images from East Legon showing a borehole with pump, a simple filtration system and a Reverse Osmosis System for purifying borehole water



Source: Fieldwork, 2011

On the issue of willingness, whilst parts of East Legon with rationed water supply could afford to put up boreholes, Ashale Botwe, a uniquely water scarce area in terms of tap water, had no choice but to put them up and even sell water to residents who could not afford the venture. Teshie, a low-income area could only afford wells, as already stated, and they get to sell water by the bucket to neighbours and make profit. Constructed tanks (above ground) were also a common feature in the study localities. In-depth interviews revealed contrasting views from the

high and low-income areas. In Teshie, its main purpose was for water sale whereas in East Legon, its function was for domestic uses only (Plate 5.2).

Plate 5. 2: Cement Tanks for Holding Water in Teshie



Source: Fieldwork, 2011

The quality from borehole water can be considered to be good, since it is a ground water resource and less likely to be polluted. However, salt intrusions from the sea, metals and anthropogenic influence may compromise the utilization of some underground water (Sommer *et al.* 2001). The location of these *holes* is very critical, especially near septic tanks and ‘soak-aways’ as wastewater could seep from septic tanks to contaminate the borehole water making it unwholesome for consumption and for any meaningful use. During field observations, most boreholes and septic tanks were found only less than 50 metres apart as against the ideal practice of 100 metres or more, apart. In the absence of this kind of pollution and excess salt, borehole water was considered the best source of water (National Water Policy, 2007).

Discussions on the role of borehole water use, at the policy level, have been going on since Ghana's surface water came under threat of pollution along the Densu River. As a result, government has taken keen interest in protecting ground water resources. The need for policy to control these at the municipal (seeping and leaching of decomposed wastes buried at landfills) and household level (soak way) cannot therefore be ignored.

5.2.2 Rainwater Harvesting

Reports by Dovie (2009) show that, severe drought, prolonged dry spells, variable rainfall regimes and rain floods of 1983, 1998, 2005 and 2007, respectively, in Ghana are examples of extreme weather events, due potentially to changes in climatic events. He also report that, because of the small land surface of Ghana, the whole country may be exposed to such changes and this can lead to important rainfall deficits and dry spells. These events alter the quality of natural resources and generally affect human security through water and food insecurity. During the fieldwork, rainwater remained one of the most important and cheapest sources of additional water for most households in the study areas. Accordingly, almost all households depend in one way or the other on rainwater as additional sources of water supply (Table 5.4).

From responses, the problem with rainwater was its unreliability, especially in this phase of climate change. Respondents interject that, during rainy periods, it rained in excess causing floods and during dry seasons, the period was longer than necessary. They were therefore not confident about rainwater harvesting. To find out actual representations of these views, a quantitative analysis was therefore done to show trends among the sampled localities (Table 5.4).

Table 5. 4: Rainwater Use in the Sampled Localities

Community	Rainwater Use		Total
	Yes	No	
East Legon	29 (48.33%)	31 (51.67%)	60 (100%)
Dansoman Estate	42 (70.00%)	18 (30.00%)	60 (100%)
Teshie	45 (75.00%)	15 (25.00%)	60(100%)
Ashale Botwe	20 (33.33%)	40 (67.00%)	60 (100%)

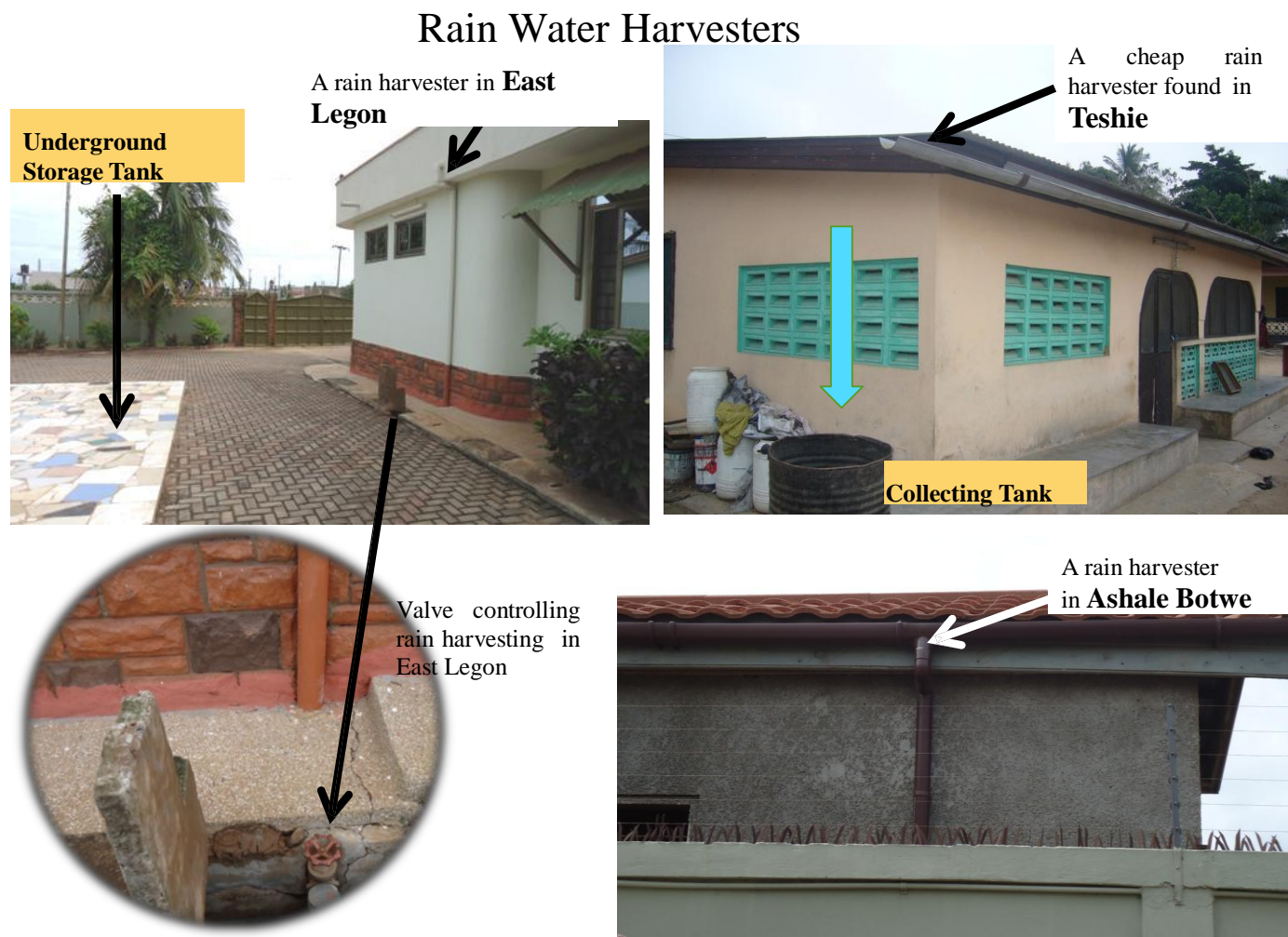
Source: Fieldwork, 2011

Generally, 56.67% respondents use rainwater whilst another 43.33% responded otherwise. About 51.67% of the respondents in East Legon and 67% in Ashale Botwe remained within the group who did not harvest rainwater as a coping mechanism. The others were Dansoman Estates, 30% and Teshie 25%. Nonetheless, more than half of the respondents in Dansoman and Teshie used rainwater representing 70% and 75%, respectively. These variations in adoption were seen in the kinds of uses the water was put to. Some used it for potable uses, others, for non-potable uses.

Some respondents during the group discussion expressed concern about the particles settling in rainwater when stored for a longer period. Others also intimated that the quality of rainwater in terms of its dark colour when stored for longer periods was questionable, especially for households who use it for potable purposes, such as cooking. However, for households who use it for non-potable purposes like washing and watering of flowers and gardens, rainwater serves as a sustainable water supply to augment other household water supply.

Common in households in some communities were underground storage devices used to collect and store rainwater. This rainwater was channeled through rain gutters from the roof of buildings to holding facilities like barrels, open tanks and underground storage devices (Plate 5.3).

Plate 5. 3: Types of Rain Harvesters and their Storage Tanks in Study Areas



Source: Fieldwork, 2011

Climate change from numerous studies is known to be a challenge to rainwater harvesting (Minia et al 2004; Bates *et. al.*, 2008; Dovie, 2009; EPA, 2009; WRI, 2010). Against this backdrop, respondents were asked if they have heard of climate change and if they consider it to have an effect on their water harvesting and how they can relate it to their coping strategies. A greater percentage of respondents responded that climate variability has indeed changed the water pattern in their localities (see Figure 5.1).

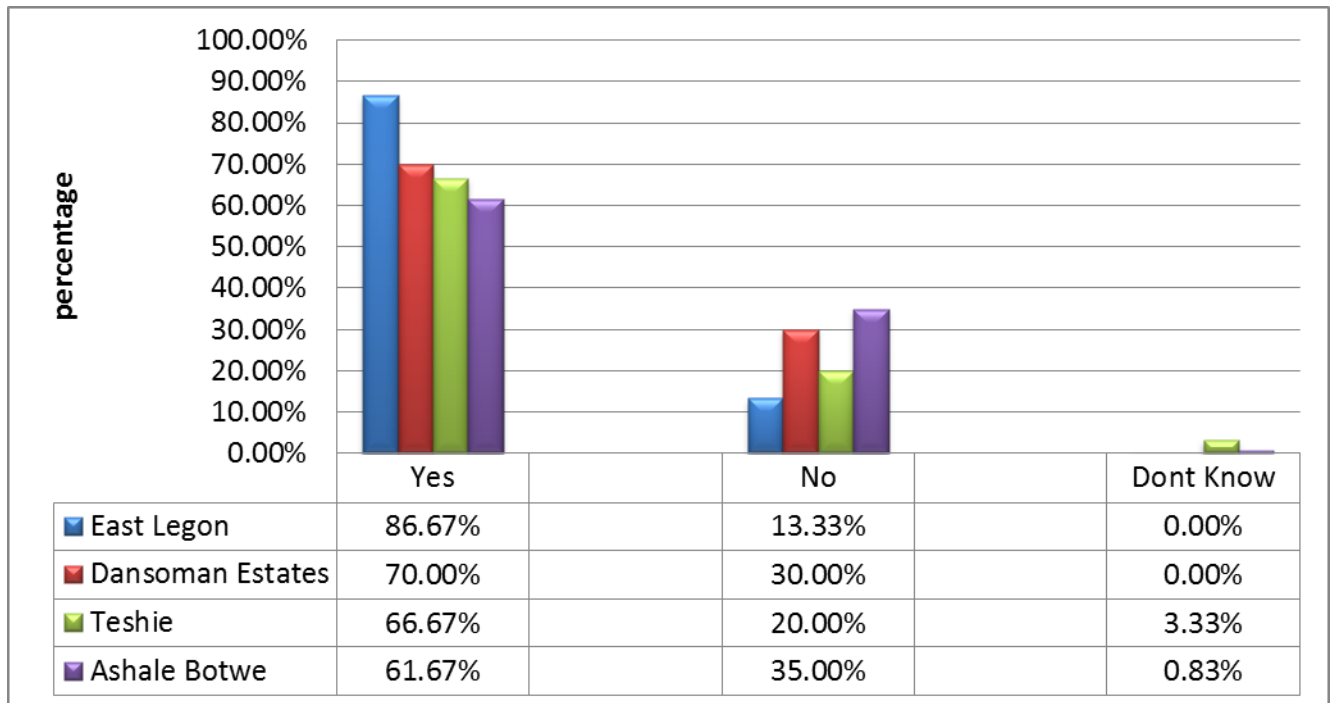


Figure 5. 1: Negative Effect of Climate Change on Water Availability in GAMA

Source: Fieldwork, 2011

From the Figure 5.1, more than 50% of respondents in three sampled localities said that for the past five years, rainfall had not been regular and were worried about its sustenance since, it is one of their major sources of water supply. One respondent in Teshie opined that:

‘We don’t receive water from Ghana government. Water from ‘God’ is also not regular. What shall we do to survive? You know we need water for every activity in the house and yet it is not available. Maybe, we will have to save wastewater to survive until the rains come and the government can think of we poor people. That is what we have been doing anyway’.

Owing to the above situation, respondents expressed concern about the increasing destruction of trees and the burning of fuel, which causes increased climate variability. When asked how they acquired this knowledge, they responded by saying, it was always on the television news and radio and they witnessed it when they travelled to neighbouring regions. One respondent also chipped in by saying:

‘‘Can’t you see the way Accra is now one with Eastern, Central and Volta region? Very soon, we will be living on the sea’’.

5.2.3 Tanker, Vendor and Neighbour Services

The occurrence of ⁸vendor, neighbour and tanker services were variable in the study areas. It must be noted that tanker service is also a form of vendor service. From the people interviewed, about 55% used one or more forms of these services. Of the three sources, tanker service was highly patronized (49.25%) followed by vendor services (41.79%) and neighbour services (8.96%). Tanker service was highest in Ashale Botwe (46.97%) and in East Legon (28.79%), whereas vendor services was highest in Ashale Botwe (44.64%) and Teshie (35.7%) (See Figure 5.2). Neighbour services were also predominant in East Legon and Dansoman (33.33%).

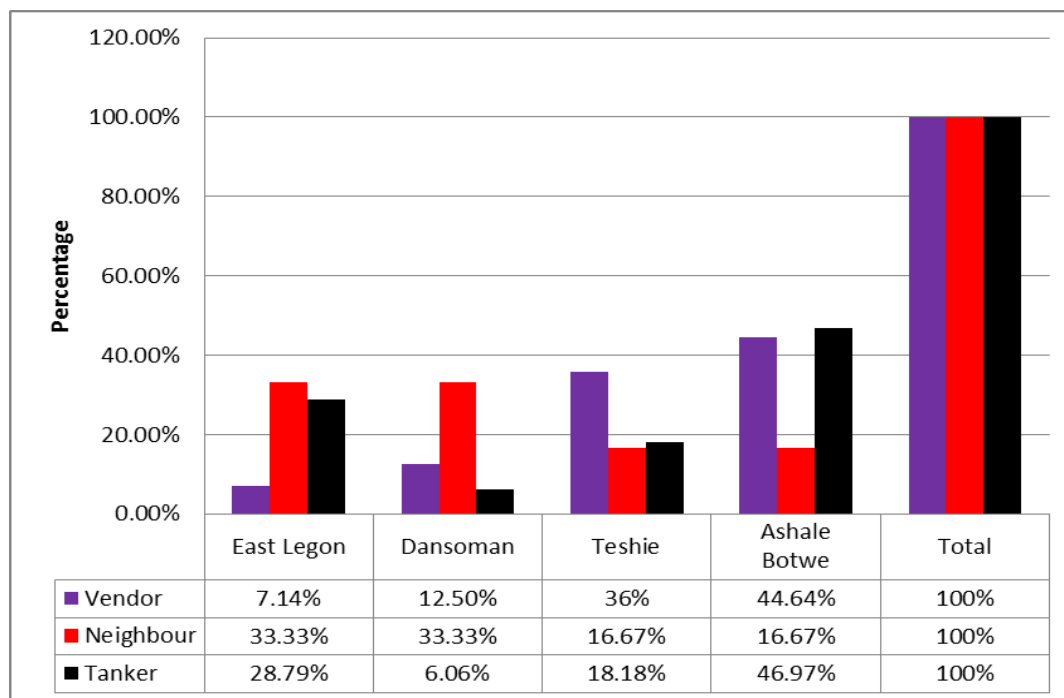


Figure 5. 2: Use of Vendor, Neighbour and Tanker Services as Additional Sources of Water in GAMA

Source: Fieldwork, 2011

⁸ Vendor service used in the work is interpreted to mean ‘paying for water by the bucket’

From the study, it was found out that, in Ashale Botwe, households derived their source of water mainly from tanker services and boreholes, whilst Teshie households derived their source mainly from both tanker service and tap water. Again, the uses that these sources of water were put to are not different from that of potable water supply, rainwater and boreholes as was shown in the previous section.

The proliferation of tanker services in Ashale Botwe was chiefly because of the lack of water-flow in the already limited pipe network systems. As such, the only way they could cope on a long-term basis was to seek the services of tanker owners who according to the respondents, sometimes took advantage of them. The cost of buying water from vendors and tanker service was extremely high, compared to what other people were paying for tap water in other localities. The quality also left much to be desired. Most residents paid as high as 120 Ghana Cedis in Ashale Botwe for the service, as compared to 6-12 Ghana Cedis of the same amount of water in Dansoman Estates from GWCL tap water. A resident in Ashale Botwe had this to say:

“We pay too high for tanker service and the quality is usually below standard. My children got sick from it last year and had to be hospitalized. The cost of water has become so high that I am planning to relocate. It is really draining our resources. Sometimes we even sell the water to recoup our investment. The government has promised better services but we are yet to see the full effect”.

This statement also shows that a lot can be said about the quality of water from neighbour, vendor and tanker services. Research by Songsore et al. (2009) indicated that, water loses its quality when transferred from the tap to secondary storage devices. This affects the health of the final consumers and ultimately impacts negatively on the socio-economic development of a nation when there is outbreak of diseases.

From the analysis thus far, it was also of interest to find out the quality of water that neighbours allowed their fellow neighbours to use freely. This was due to observations made during the survey when respondents complained about the quality of water they had to use from their neighbours. The findings conclusively showed that, most people ‘rich’ in water will ultimately give out water they do not need. This was water from constructed tanks, which sometimes contained alga growth, and sometimes from their wells. A few, however shared their clean sources. A young woman who I spoke with, on her way to fetch water in Ashale Botwe, stated:

“Each time I go to fetch from the opposite house, they direct us to the back of the house where an old tank stands. This tank is not covered and is heavily polluted. The surface is always full of debris with green- green substances in it. I always boil the water before using it. Some people who also fetch do not boil theirs. We do not have a choice but to take it as it is and make the best out of it”.

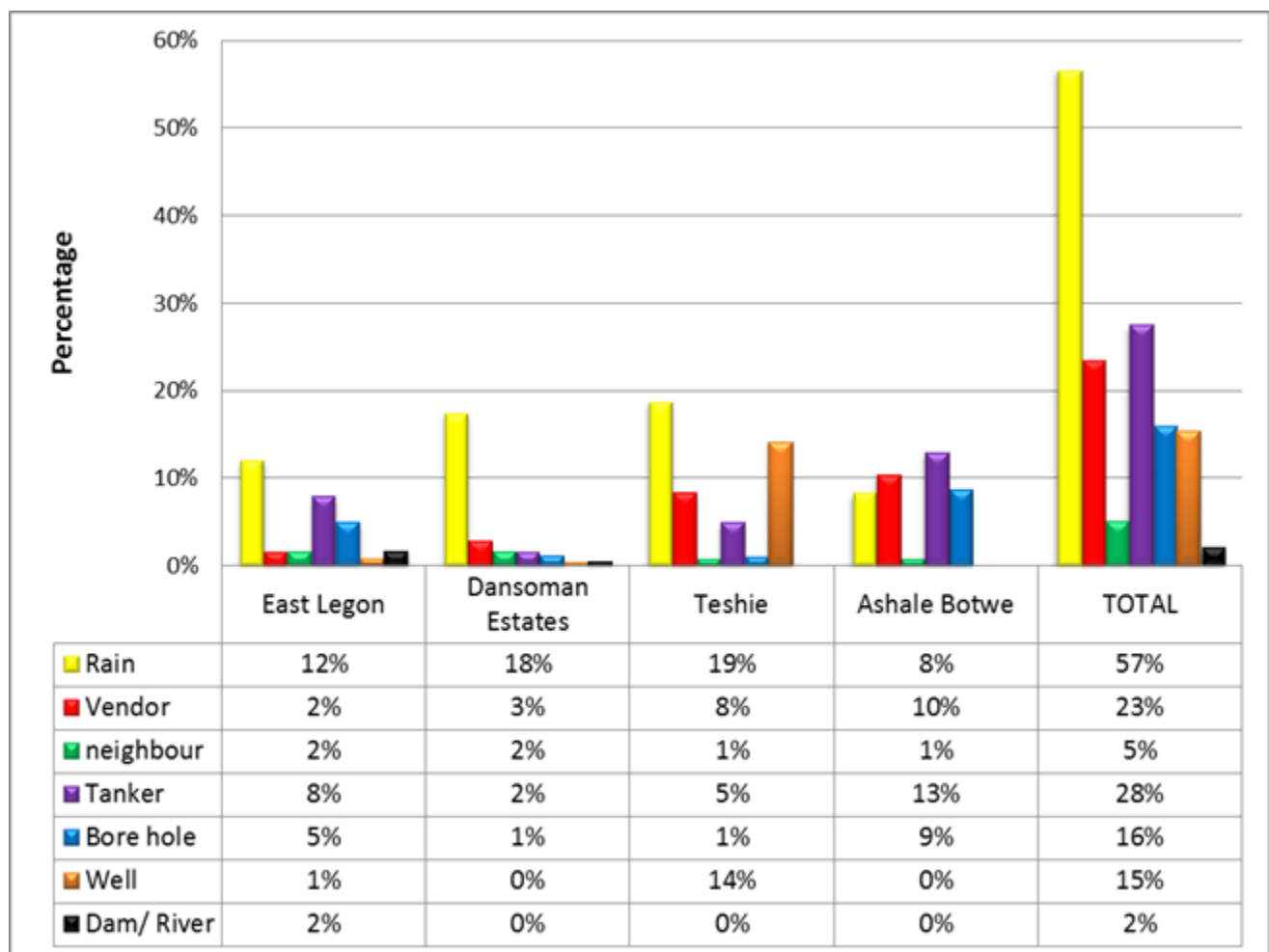
One will therefore ‘jump’ to argue that, the ‘water-rich’ people were selfish but a closer look revealed through in-depth interactions, that it was a clear issue of survival as far as water related issues were concerned, especially as government does not practice and enforce equitable distribution of water resources.

5.2.4 Synthesis of Supply Adaptation Measures

A summary of all supply adaptation measures is presented in Figure 5.3 to show the disparity. The findings from this study revealed that people from different residential areas, namely East Legon, Ashale Botwe, Dansoman Estates and Teshie respond differently to the various water situations. Whilst for some, water supply was a matter of affordability and choice, for others, it was not a question of preference but desperation. Generally, decisions were taken not only with potable sources (pipe-borne) of water, but also with non-potable sources, like wells and rivers.

This study concluded that, rainwater use was the most common and cheapest source of water and its

usage cuts across the entire study area. However, it was not the preferred choice upon further interrogations due to its unreliability. Tanker service, according to responses was the most preferred choice, but the cost was high. Respondents considered water from tanker service safe to use, although it is not always the case and less likely to make them sick, since it was often directly from GWCL. The respondents did not see the borehole water, an underground water resource as the safest, since it contained many minerals like salt, iron and fluoride and could also be polluted by human activity.



⁹Figure 5. 3: A Summary of all coping Mechanisms for the Study Areas in GAMA

Source: Fieldwork, 2011

⁹ Multiple responses of all coping mechanisms in the study areas

This study therefore contradicted the works of Singh et. al., (2004) who stressed that underground water resource was free from pollution and could serve as a potable source of water in developing countries. To overcome these, some residents in high-income areas found solutions, like the use of filters to help purify the water to an appreciable state. The study further concluded that vendor, rain, well and river water use was mainly common among the poor. The findings of the coping mechanisms also demonstrates that there is the need to adequately understand the water gathering process, its storage and uses, as well as the quality concerns of the people.

5.3 Water Demand Management: Learning to Live With Less Water

In Section 5.2, a number of supply coping mechanisms emerged in response to households' stress over water. Accordingly, it is important to examine issues of demand management that households in the diverse income classes undertake to support the supply adaptation measures. Demand management is what end-users of the potable water undertake to manage the water they acquire from all sources. The issue of demand management has been addressed at the global, national, regional and local context. Each of these contexts has been clearly defined in a demand management framework used for this study called 'Slowing the flow' by Lawton et. al. (2008). The framework shows the fundamental basis on which a policy framework constituting regulations (laws), non-regulatory policy and economic instruments are based. Specific mechanisms used include maintenance, water efficient technologies and tools like water metering (Lawton et. al., 2008).

5.3.1 Water Use Patterns Among Accra's Privileged Classes and Labouring Poor

It is an established fact that high income earners consume large quantities of water because of their everyday needs. However, we forget to equate this consumption pattern with their location pattern. The location pattern of water use in Accra can be grouped into urban, periurban and rural areas. Whereas the high-income groups who live in urban areas like East Legon consume large quantities of water, the 'water poor' in peri-urban areas and sometimes rural areas lack access to adequate water. Such instances were found in Ashale Botwe. Peri-urban and rural areas generally lack the political means to improve their access to water services in a way that is affordable to them and therefore, they tend to be more vulnerable than high-income areas. To guide and aid the comparison of demand management issues among sampled localities, the study sought to find out the forms, types and management of storage equipment used by respondents, as well as metering and payment modes for pipe-borne water. This was because, the study anticipated that these will vary among localities and will ultimately influence conclusions. The issue of GWCL connections, water metering and billing were investigated on the field. With the exception of Ashale Botwe, the other three sampled areas were mostly connected (Table 5.5).

Table 5. 5: Pipe Connections in the Sampled Localities

Community	Percentage of pipe connections			Total
	Yes	No	Non Applicable ¹⁰	
East Legon	96.7%	3.3%	0%	100%
Dansoman Estate	100%	0%	0%	100%
Teshie	63.3%	10.0%	26.7%	100%
Ashale Botwe	0%	0%	100%	100%
Total	65.0%	3.3%	31.7%	100%

Source: Fieldwork, 2011

¹⁰ The NAs were respondents who had no pipe network in the area, hence could not answer the question. Question was therefore not applicable to them. This was common in Ashale Botwe and parts of Teshie

For those who were connected (65%), the study sought to find out the availability of functioning water meters and how regularly they receive their bills. According to the data in Table 5.6, Dansoman Estates recorded 100% of water meters, East Legon, 96%, Teshie 63.3% and Ashale Botwe 0% in terms of availability.

Table 5. 6: Availability of Water Meters in the Sampled Localities

Community Total	Percentage of water meters			
	Yes	No	Missing/NA	
East Legon	96.7%	3.3%	0%	100%
Dansoman Estate	100%	0%	0%	100%
Teshie	63.3%	10.0%	26.7%	100%
Ashale Botwe	0%	0%	100%	100%
Total	65.0%	3.3%	31.7%	100%

Source: Fieldwork, 2011

On the issue of regular billing, responses varied. Some received their bills on time, whilst others did not. A few had to collect their bills themselves and one consumer had this to say:

“I have stayed in this house for 10years and each month I personally visit the GWCL office to collect my bill in order to make payments. I have informed them on countless occasions to come and rectify the situation in my house to no avail”.

Respondents of Ashale Botwe, who lack meters in the area, as a result of lack of connection to GWCL pipe networks, lamented that they had no use for meters, in contrast to the other three localities. However, upon further interrogation in the other three areas, 50% of these meters were defective or had been disconnected, so the customers were made to pay flat rates. Flat rate is when one pays bills based on ‘best estimates’ of past consumption pattern using household size and type of dwelling (PURC, 2011). This method according to GWCL officials was not economically productive for the company, as household size kept changing and they

did not have enough logistics to track these changes to amend their tariffs. To solve the problem, they had embarked on an exercise to replace all old meters in the system, which is still ongoing. These findings were verified in the households as indeed, new meters were being installed but consumers complained of the slow progress of replacements.

For most urban households, storage of water as a coping strategy was critical for the smooth running of their homes. Residents in all the four study areas stored water. Nevertheless, what differentiated each area was the type and capacity of storage equipment, directly related to the water situation and economic status of the locality. Whilst residents of East Legon stored water in containers with capacity ranging from 1000litres to 10,000litres, low income areas like Teshie used smaller containers and gallons, ranging from 20litres to 100litres for storing water (Plate 5.4). Refill intervals therefore became shorter and cost of water, higher in Teshie than it was for East Legon. This was because buying a good or service, in this case water, in smaller quantities over a period was more expensive than buying in bulk. This can be better expressed by the concept of retailing and wholesaling. The net effect was that Teshie spends more money to acquire water than East Legon.

Plate 5. 4: Storage Containers of Varying Sizes



Source: Fieldwork, 2011

Findings in Dansoman Estate, a middle-income area, also showed a range of storage containers ranging from 100litres to 1000litres. Ashale Botwe also made use of containers of varying sizes ranging from 1000litres to 5000litres. The reason for the disparity in Dansoman and Ashale Botwe, although both are middle-income areas, can be attributed to their water situation and not income. Whilst Dansoman has good pipe water supply and therefore has no eminent need to store water in large quantities, Ashale Botwe, with limited network and mostly relying on tanker services, found it prudent to store water in larger quantities.

Table 5.7 shows the refill intervals of storage containers in the sampled localities. The intervals used were daily, weekly, monthly and other. The 'other' category, based on field responses was

recorded to be very high. It was interpreted to be bi-weekly and refill as and when water flowed from taps into storage containers. This was hardly observed by residents because of the direct connection of these pipes to the storage devices. This ‘other’ category was recorded in East Legon and Dansoman Estates as 71.7% and 66.7% respectively (Table 5.7). Teshie refill was highest on a weekly basis (76.7%) whereas Ashale Botwe’s refill was distributed almost evenly over the entire categories.

Table 5. 7: Water Storage Refill Interval in the Sampled Localities

Community	Storage containers refill interval				
	Daily	Weekly	Monthly	Other	
East Legon	13.3%	6.7%	8.3%	71.7%	100%
Dansoman Estate	0%	33.3%	0%	66.7%	100%
Teshie	10.0%	76.7%	0%	13.3%	100%
Ashale Botwe	31.7%	25.0%	25.0%	18.3%	100%
Total	13.8%	35.4%	8.3%	42.5%	100%

Source: Fieldwork, 2011

Despite the differences in container size in East Legon and Teshie, the refill rate was higher in East Legon (daily/ weekly/biweekly) despite their huge container sizes than Teshie (weekly basis) due to the demand in the former. At the local level, especially among the low-income groups in peri-urban and urban areas, results showed that the problem of lack of water cannot be considered as homogeneous, because of the differing needs, perceptions, and tasks experienced by respondents. This was true not only for different households in the study area, but especially, for different members within households like men, women and children. Women and children were often affected by the lack of potable water service as they are responsible for fetching water and performing water-demanding activities, which also meant that, they are more exposed to water related diseases (Allen et al, 2006).

5.3.2 Excessive Use of Water by the Wealthy, Minimum Use by the Poor

Standards about what the minimum amount of water a person needs range from 35l/c/d in developing countries according to WHO (2000) report and 120-140l/c/d according to GWCL planning data (2011). In the study area, water use among the income classes varied widely with the highest use in East Legon and Dansoman Estates (more than 400litres per day) and the lowest use in Teshie and Ashale Botwe (predominantly in the 50-200 litres per day categories) (Figure 5.4).

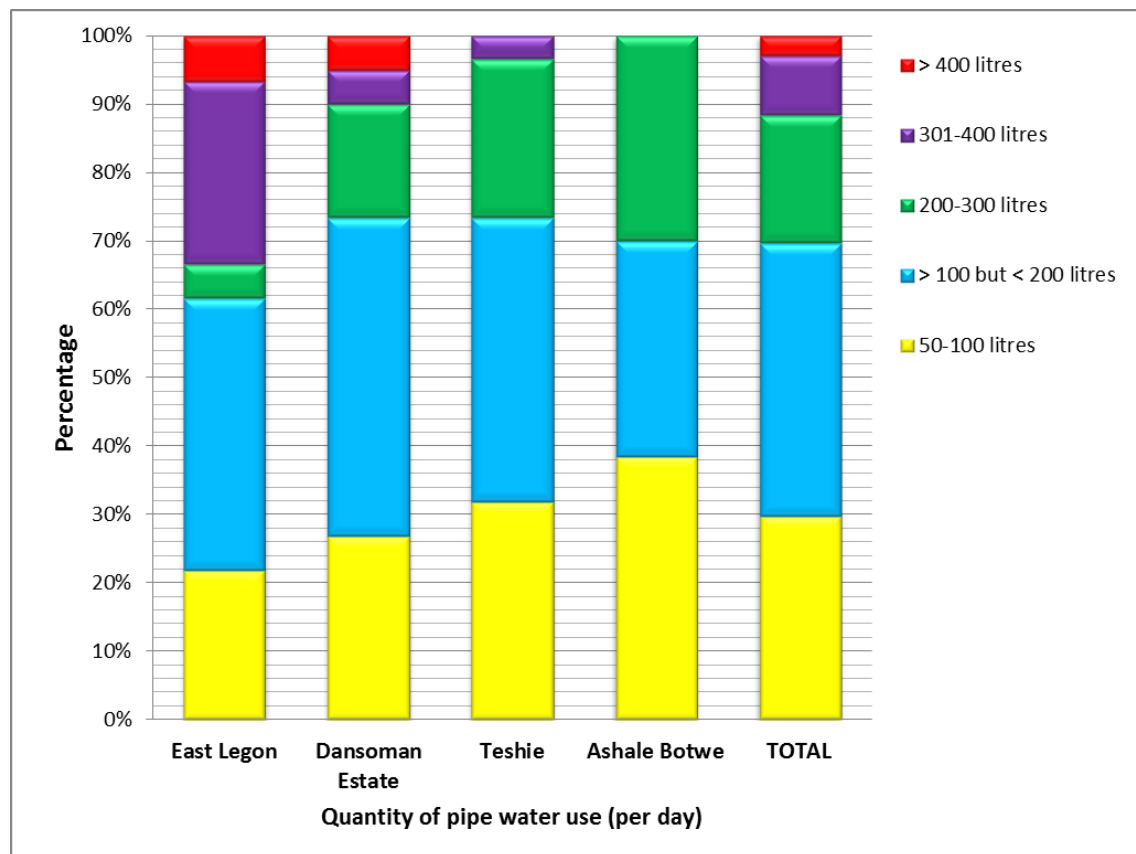


Figure 5. 4: Estimate of Pipe Water Use by Household by Residential Area

Source: Fieldwork, 2011

The question of which household activity consumed the most water was inquired. From Table 5.8, several water-consuming activities were identified in the study areas. The Kendall's Coefficient of Concordance (W) indicates that there were 80.9% (0.809) agreement among rankings by households and this was significant at 1% (Table 5.8). Therefore, it can be concluded that there is a very high degree of agreement among the respondents in the ranking of the household facility that consumed the most potable water resource in the study area. The difference in the levels of agreement (19.1%) may be due to the heterogeneous nature of the income classes and social status. Toilet flushing was the most water-demanding activity with a mean score of 1.85 whilst other activities (car washing, dish washers) was found to be the least water demanding activity in the study area with a mean score of 5.93 (Table 5.8).

Table 5. 8: Ranks of Water Consuming Activities in Households

Constraints	Mean Score	Rank
Toilet flushing	1.85	1 st
Bathing	1.88	2 nd
Laundry	2.57	3 rd
Cooking	3.92	4 th
Watering	4.86	5 th
Others	5.93	6 th
N	149	
Kendall's W	0.809	
df	5	
Asymptotic significance	0.000***	

*** indicates significant at 1%

Source: Fieldwork, 2011

In high-income areas, where they consumed lots of water, it was common to find lots of household fittings that consume lots of water (Chapter 4). These fittings include non-green reticulation systems, such as large showerheads, washing machines, Jacuzzis, swimming pools, and water fountains (Plate 5.5). It is easy to find garden hose with water running longer than necessary for watering lawns, taps left running when brushing teeth, taking a shower instead of a bath and washing cars with clean potable water.

Plate 5. 5: High Use of Water in High-Income Areas



Source: Fieldwork, 2011

In low-income areas, the reverse is the case, where baths are taken using buckets, and KVIP toilets were common, instead of flush toilets. Luxurious items like washing machines, dishwashers and flush toilets were absent, hence minimal use of water is practiced. Some even collect rainwater in a bucket for domestic purposes like cooking and cleaning. Yet, their expenditure on water was very high, due to the mode of acquisition. During the fieldwork, one respondent expressed an attitude of excessive use of water in East Legon;

‘My water bill is too low and I don’t understand why I pay less than GH¢10 for water so any time it flows, I leave my water-hose on for hours so that my water bill will be higher’.

When asked if she was metered, she responded in the affirmative but claimed that her readings were so low compared to what she pays for other utilities like electricity and telephone bills.

5.4 Chapter Summary

The highlight of this chapter was to identify existing informal arrangements households undertake to cope with water stresses. This objective was based on the assumptions that households who resort to various coping mechanisms may be influenced by local conditions in the various urban and rural environments. These coping mechanisms were divided into supply adaptation measures and demand management measure. Supply adaptation measures include rainwater use, borehole/well water use, wastewater reuse, tanker and vending services, as well as neighbour water use. Rainwater use was the most common and cheapest source of water, as reported by all respondents, but not the preferred choice due to its unreliability. Tanker service, according to responses, was the most preferred choice but it was expensive. Water from tanker service was considered safe to use and less likely to be polluted, since it was often directly from GWCL. The respondents did not see the borehole water, an underground water resource as perceived by most studies to be the safest, since it contained many minerals like

salts, iron and fluoride.

Demand management on the other hand, is what end-users of the potable water undertake to manage the water they acquire from supply sources like tanker service, rainwater and potable water sources. Some of these measures were seen in the type and size of storage equipment, use of water meters for efficient billing purposes, and finally, the most-water-consuming activities and how to manage them in the home, which were found to be toilet flushing, bathing, laundry services, and lawn watering. In sum, high-income areas used the most water for activities like lawn watering, in swimming pools and for washing machines, hence had a lot to do in adopting water demand management measures.

CHAPTER 6 WASTEWATER REUSE AS AN ADAPTATION MEASURE

6.1 Introduction

Fresh water is said to be a critical capital resource and as such requires a management policy that ensures absolute sustainability of both quality and quantity for current and future users (Jones and Hollier, 1997). To implement such a policy requires the use of a demand management strategy (Jones and Hollier, 1997). Accordingly, Mfalila (2000) defines demand management as the development and implementation of strategies aimed at influencing demand, to achieve efficient and sustainable use of a scarce resource taking into account economic, social and environmental considerations. He further notes that besides efficiency, it promotes equity and environmental integrity. NRA (1994) also defines it as the management of the total quantity of water abstracted from a source of supply along with the use of measures to control waste and consumption. Demand management approach includes key factors like policy framework, sustainability, efficient and equitable use and control waste of the resource.

It has been demonstrated in many countries that saving water rather than the development of new sources is often the best 'next' source of water, both from an economic and from an environmental point of view (Khouzam, 2003). This is what water demand management seeks to achieve. Water demand management is therefore seen as the preferred alternative to meet increasing water demand. It differs from supply management in that it targets the 'water user,' rather than the 'water supplier,' to achieve more desirable allocations and sustainable use of water (Bruvold, 1998; Mfalila, 2000; Vigneswaran and Sundaravadivel, 2004; Hartley, 2005; Yang and Abbaspour, 2007). Apart from structural measures, like low-flush cisterns for toilets, leak detection, reuse and drip irrigation in agriculture, demand management strategies also consist of non-structural measures like economic and legal incentives (as stated above) to change the behavior of water users and

the creation of the institutional and policy environment that enables this approach (Savenije and van der Zang, 2002).

Wastewater reuse, as an emerging demand management measure the world over, is the focus of this chapter, highlighting on reuse in its traditional form in the sampled localities of GAMA. Emphasis is on the potential for reuse and the basic means by which respondents are making use of the wastewater. An analysis of the type of drainage system found in the study localities is shown in Table 6.1 to give an insight into some of the conditions that may influence reuse. The types of drainage system found, based on literature and considered for the study include septic tank, soak-away, closed gutters, open gutters and no drainage system. The type of drainage systems used here showed how respondents dispose off their sewage or sullage wastewater.

Table 6. 1: The Drainage Systems Found in the Sampled Localities (multiple responses)

Community	Type of Drainage System				
	Septic Tank	Soak-Away	Closed Gutters	Open Gutters	No Drainage
East Legon	91.7%	76.7%	6.7%	6.7%	0%
Dansoman Estate	90.0%	31.7%	13.3%	26.7%	0%
Teshie	13.3%	6.7%	0%	60.0%	38.3%
Ashale Botwe	46.7%	51.7%	0%	25.0%	45.0%
Total	60.4%	41.7%	5.0%	29.6%	20.8%

Source: Fieldwork, 2011

The presence of septic tanks meant that they have flush toilets and this was only dominant in some of the areas. From Table 6.1, most of these tanks were located in East Legon (91.7%) and Dansoman Estates (90%) whilst most of Teshie and parts of Ashale Botwe had no septic tanks.

This meant that the latter areas had no flush toilets and mostly made use of KVIPS, bucket latrines, etc. From the table, open gutters were dominant in Teshie (60%) while Ashale Botwe and Teshie recorded areas with no drainage system, 45% and 38.3%, respectively. This meant that, such areas usually disposed off their wastewater on open compound. One would therefore expect that, the development of reuse practices would be best suited to East Legon and Dansoman Estates environments and less so in Teshie and/or Ashale Botwe. However, the mode in which the wastewater is collected and the use is the important consideration, as it may invariably be possible in all types of localities, irrespective of the type of drainage system available.

6.2 Knowledge and Awareness of Wastewater Reuse at the Household Level

Public awareness efforts, based solely on scientific data, do not necessarily increase public acceptance of projects (Robinson et al., 2005). Public policy on wastewater reuse options must include the human dimension, since it is the public who will be served by, and pay for, the option. Determinants associated with waste management issues are complex, but this does not lessen the importance of fully understanding these concerns if interventions are to be successful. The challenge is to identify public knowledge and perceptions and systematically address concerns through a framework of educational, policy and management strategies (Robinson et al, 2005). Robinson (2002) notes that there have been a number of studies, experiences, reports and training programs about successful and non-successful efforts to gain and maintain public acceptance of reclaimed water uses. These studies come with several barriers of implementation that must be overcome if development is to be achieved.

Against this backdrop, attempts were made during the fieldwork, to probe further into some of these barriers. The first issue, which was raised during the study, was whether respondents had

any knowledge of wastewater reuse. It was anticipated that knowledge about the resource relates to attitudes concerning water reuse. As a result, responses gathered from the field (represented in Table 6.2) showed that majority of people, representing about 84% of the respondents, had knowledge about wastewater reuse. Nevertheless, chi square results show that differences in knowledge of reuse were not significant amongst all four localities. Chi square value of 0.562 revealed that the expected means were higher when tested at $p < 0.05$, hence no significant relationship exist between knowledge and the type of locality (Table 6.2). Knowledge of reuse was again, tested with education and income level variables, which also revealed similar patterns. Accordingly, majority of respondents knew about wastewater reuse. It was found to be common knowledge, hence irrespective of locality, socio-economic status or education, majority of the people, were aware of the existence of water reuse.

Table 6. 2: Respondents Knowledge about Wastewater Reuse;

Community	Yes	No
East Legon	50 (83.33%)	10 (16.67%)
Dansoman Estate	52 (86.67%)	8 (13.33%)
Teshie	47 (78.33%)	13 (21.67%)
Ashale Botwe	52 (86.67%)	8 (13.33%)
Total	201 (83.75%)	39 (16.25%)
$X^2=2.051$	P – value =0.562	

Source: Fieldwork, 2011

6.2.1 Uses of Wastewater at the Community and Income Level

Following the issue of knowledge and awareness, respondents were then asked if they reuse any form of their wastewater (Table 6.3). High percentages were recorded in Ashale Botwe

(91.67%), followed by Teshie (86.67%), Dansoman Estates (81.67%), with the least re-use in East Legon (60.00%). Although high frequencies were recorded in general, there were marked significant levels among study localities of the high and low socio-economic groups using the chi square test. The χ^2 value of 0.00 shows that the expected means are lower as compared to the observed means hence highly significant relationship was established. In summary for all areas surveyed, the percentage of users stood at 80%. Of the 20% who were not reusing, further investigation indicated that, 73.2% expressed willingness to reuse wastewater if the option was made attractive by way of the government creating effective education and awareness programmes.

Table 6. 3: Respondents Use of Wastewater

Community	Yes	No
East Legon	36 (60.00%)	24 (40.00%)
Dansoman Estate	49(81.67%)	11 (18.33%)
Teshie	52 (86.67%)	8 (13.33%)
Ashale Botwe	55 (91.67%)	5 (8.33%)
Total	192 (80.00%)	48 (20.00%)
$X^2=21.875$	P-value = 0.000***	

*****indicates significant at $p < 0.01$**

Source: Fieldwork, 2011

The highest recorded use in Ashale Botwe is explained by their low water availability and their willingness to adopt a wider range of coping mechanisms. For Teshie, explanation from data was the low-income status of the community and the low cost of wastewater reuse hence, its easy adoption. In Dansoman and East Legon, lower reuse was observed because of their more reliable water sources and high-income level presenting other acceptable options than reuse.

Further analysis was done with income level and willingness to reuse wastewater (Table 6.4). The study found out that the higher income group recorded lower reuse than the lower income groups, thus a marked continuous decline in reuse from the low-income groups to the high-income groups. Through additional analysis, these were explained by the wider choices of coping mechanism for high-income groups, some of which include borehole water use, rainwater harvesting, and tanker service. Consequently, willingness to use wastewater was influenced by other factors apart from mere knowledge.

Table 6. 4: Relationship between Income and use of Wastewater

Average Monthly Earnings	Yes	No
<Gh ¢200	50 (89.29%)	6 (10.71%)
Gh ¢200 - 500	47(87.04%)	7 (12.96%)
Gh ¢500 - 1000	31(75.61%)	10 (24.39%)
Gh ¢1000 - 1500	22 (88.00%)	3 (12.00%)
> Gh ¢1500	16 (64.00%)	9 (36.00%)
Other	26 (66.67%)	13 (33.33%)
Total	192 (80.00%)	48 (20.00%)
$X^2 = 14.516$	P – value = 0.013**	

****indicates significance at $p < 0.05$**

Source: Fieldwork, 2011

The ‘other’ category, which was also quite high (66.67%), influenced results (Table 6.4). They included categories of students above 20 years and adults on pension.

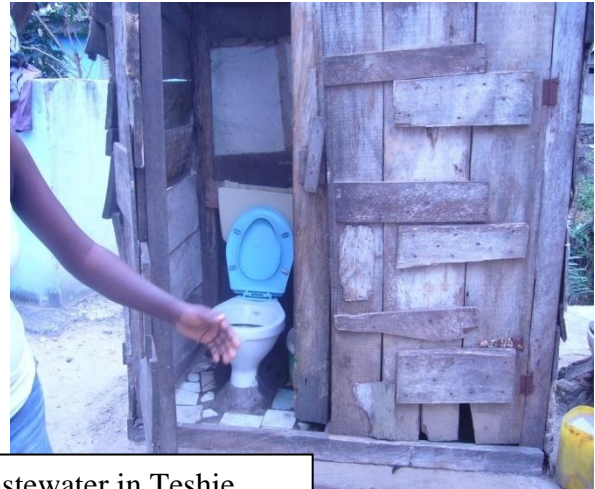
6.2.2 Reuse Activities in Sampled Localities

Based on the above responses, further in-depth interviews were focused on the uses wastewater was put to, or likely to be put to, if given the opportunity. All affected respondents expressed varied views. Notable among them were uses for scrubbing bathhouses, backyard gardening and further laundry work. All respondents expressed grave interest in using wastewater for toilet flushing purposes, because of its benefits in saving potable water. The discussions also revealed that the uses wastewater was put to depend largely on the socio-economic status of the locality. Whilst residents in East Legon will not use wastewater to wash plates, respondents in Teshie found it convenient. Uses for toilet flushing were mostly practiced in Ashale Botwe and seldom in Dansoman Estates and East Legon. In Teshie, residents expressed interest in reusing wastewater to flush toilet when their income will allow them to purchase toilet bowls. Meanwhile, others in Teshie were already practicing some form of toilet flushing with wastewater as shown in the Plate 6.1.

Plate 6. 1: Wastewater Reuse in Different Household Infrastructural Settings in Study Localities



Toilet bowls flushed with wastewater in Teshie



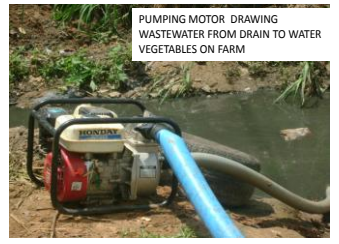
Backyard Garden in Dansoman Estates

WASTEWATER USE IN URBAN AGRICULTURE

HAND - DUG WELL SUPPLYING WATER FOR FARMING



PUMPING MOTOR DRAWING WASTEWATER FROM DRAIN TO WATER VEGETABLES ON FARM



CHEMICALS USED TO KILL SOME PATHOGENS IN WASTEWATER IN EAST LEGON BEFORE APPLYING ON FARM



Mitten Chemical

Source: Fieldwork, 2011

6.3 Sources of Wastewater at the Household Level

Respondents were also probed about their preferred sources of the wastewater. From literature, several sources of wastewater were identified which the study anticipated would influence reuse. Although respondents were willing to reuse or are actually reusing wastewater, the source of wastewater was very crucial as it did influence uses to which it was put to. On this basis, the sources identified were categorized into sinks, laundry, bath, sewage and other sources (Figure 6.1). From the figure the most preferred choice was laundry wastewater (80%) followed by bath (20.4%), sinks (2.5%), other sources (4.2%) and sewage (0%), respectively.

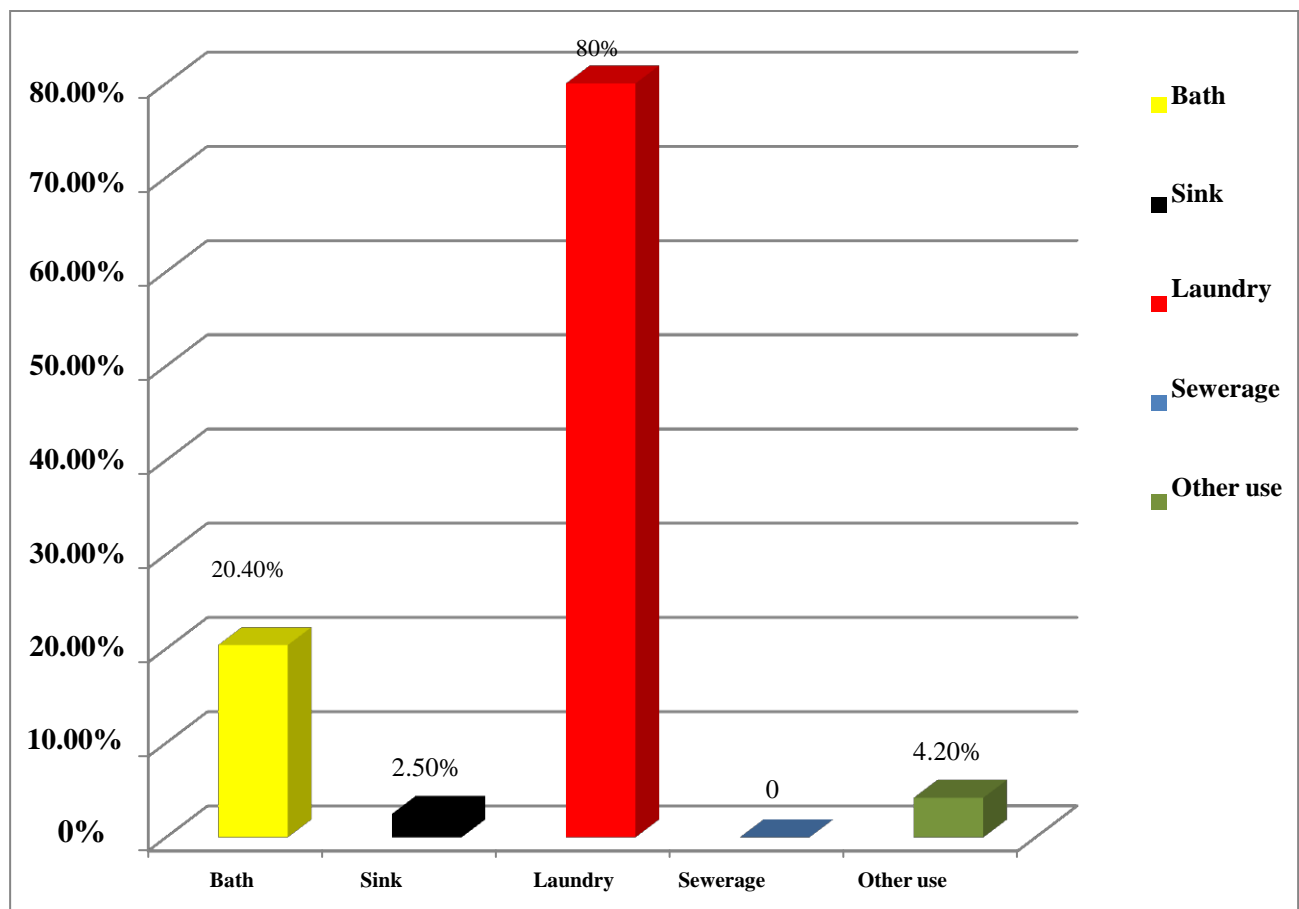


Figure 6. 1: Sources of Wastewater for Reuse

Source: Fieldwork, 2011

Whilst the gap between laundry wastewater use and the rest was very wide, the use of sewage for reuse purposes was unanimously shunned among respondents. Table 6.5 shows the views expressed by the residents in East Legon, Dansoman Estates, Teshie and Ashale Botwe.

Table 6. 5: Patterns of Wastewater Use by Residential Areas

Sources of WW	$X^2(p\text{-value})$ (%)
Bath	
East Legon	1%
Dansoman Estates	2%
Teshie	12%
Ashale Botwe	4%
Total	20.4%
$X^2=47.261$	P – value = 0.000***
Sink	
East Legon	1%
Dansoman Estates	0%
Teshie	1%
Ashale Botwe	1%
Total	2.5
$X^2=0.562$	P – value = 2.051
Laundry	
East Legon	14%
Dansoman Estates	20%
Teshie	20%
Ashale Botwe	24%
Total	80%
$X^2=33.542$	P – value =0.000***
Sewerage	
East Legon	0%
Dansoman Estates	0%
Teshie	0%
Ashale Botwe	0%
Total	0%
$X^2=0$	P – value = n/a
Other	
East Legon	15%
Dansoman Estates	22%
Teshie	33%
Ashale Botwe	29%
Total	4.2%
$X^2=11.27$	P – value = 0.010***

***indicates significant at $p < 0.01$

The general preference in all sampled localities, again, was for laundry wastewater, except Teshie, which recorded a high reuse of bath water as well. The reason for the high reuse in Teshie was that, the drainage system in Teshie as noted earlier in the introduction is poor (Table 6.1). As a result, residents during bath times, use constructed containers and old buckets to ‘catch’ the waste (Plate 6.2). This, they either utilize to suppress dust on their compounds, or save it for flushing toilets, or even use to clean their gutters, where available.

Plate 6. 2: Wastewater from Bathhouses in Teshie



Source: Fieldwork, 2011

The study revealed that laundry and bath wastewater showed a chi square value of 47.26 ($X^2 = 47.26$) and 33.54 ($X^2 = 33.54$), respectively, and these were statistically significant, indicating that there is a strong relationship between residential areas and laundry as well as bath wastewater. The other variable (e.g. general cleaning, carwash) was also significant at $p < 0.01$ with a chi square value of 11.27 ($X^2 = 11.27$) (Table 6.5). The rest (sink and sewerage) were, however, not significant.

The preference for laundry wastewater was confirmed by most of the respondents during the focus group discussions. They said it was easy to ‘accept’ and reuse wastewater as compared to the others. One young woman said;

“I usually add bleach to my laundry wastewater anytime I want to reuse it again. It makes it clear and pleasant to the eyes so that it is hard to tell where it is from. I think that is the only source of wastewater I will use whenever I need it (Reb Addo, July, 2011)”

6.4 Determinants of Wastewater Reuse at the Household Level

A model to find out determinants of wastewater reuse was developed using the Binary Logistic Regression (BLR), with reference category analysis. The model tried to find out whether respondents use of wastewater in the four study localities being the main dependent variable is significant, controlling the other selected independent variables, namely age, sex, religion, quantity of water use by households, income level and educational level of respondents. The Binary Logistic Regression depicted marital status, level of education, religion, house type and quantity of water use as significant predictors of wastewater reuse.

Table 6.6, 6.7, and 6.8 show results of odd ratio of logistic regression for individual characteristics predicting respondents’ use of wastewater in the study area. Odd ratio is a measure of effective size describing the strength of association between two binary data values like the Reference Category, RC (control group) and the other values (experimental group). The results show that many variables are statistically significant at $p < 0.01, 0.5, 0.1$. The Reference Category (RC) is accorded the highest probability of reusing wastewater, with a value of one (RC=1).

Table 6. 6: Multivariate correlates of demographic characteristics and wastewater reuse: Model 1

Predictable variables	Wastewater Reuse		
	Odd Ratio (OR)	Z- Value	P-Value
Ethnicity			
Ga Adangbe	RC		
Akan	2.8940	1.59	0.111
Ewe	2.9592	1.38	0.167
Others	1.3885	0.36	0.718
Age			
20-30 years	RC		
31-40	0.0999***	-2.63	0.008
41-50	0.3694	-1.28	0.202
51-60	0.1003***	-2.70	0.007
61+	0.0751***	-2.66	0.008
Marital Status			
single	RC		
Married	8.0323***	3.35	0.001
Separated/widowed/divorced	24.097***	3.16	0.002
Religion			
Christian	RC		
Muslim	2.9352	1.09	0.276
Others	0.2944*	-1.70	0.089

*** indicates significant at $p < 0.01$, **indicates significant at $p < 0.05$ and *indicates significant at $p < 0.1$

Source: Fieldwork, 2011

With Age 20-30 years as RC, the probability that ages ranging between 31-40years, 41-50 years, 51-60 years and 61+ years reusing wastewater is 0.099 times, 0.100 times and 0.075 times lower than the RC (20-30 years), with significant values of 0.008, 0.007 and 0.008, respectively. This means that, these age groups have a lower probability of reusing wastewater compared to their counterpart within the ages 20-30 years in the selected communities.

Marital status (Married) was highly significant and have an 8.032 (OR = 8.032) odd ratios for wastewater reuse compared to the reference category (single). Marital status (Separated/widowed/divorced) was also statistically significant at 1% and have a 24.097 (OR =

24.097) odd ratio for the reuse of wastewater as compared to the reference category. The significance of the responses could be tied to the presence of children and spouses hence increased need for water and reuse options.

Table 6. 7: Multivariate correlates of demographic characteristics and wastewater reuse: Model 2

Predictable variables	Wastewater Reuse		
	Odd ratio	Z- value	P-value
Educational Level			
None to primary level	RC		
Middle/ JHS	0.4738	-0.65	0.516
Secondary	0.1708*	-1.94	0.053
Tertiary	1.1643	0.17	0.865
Household Size			
1-5	RC		
6-10	1.6645	0.92	0.358
1-41+	0.3086	-1.16	0.246
Type of Toilet Facility			
water closet	RC		
Pit / bucket	1.8464	0.84	0.403
public toilet	0.2651	-1.39	0.166
House Type			
Compound	RC		
Detached	0.1510**	-2.53	0.011
Semi-detached	0.0511***	-3.16	0.002
Apartment	0.1016***	-2.63	0.009

*** indicates significant at $p < 0.01$, **indicates significant at $p < 0.05$ and *indicates significant at $p < 0.1$

Source: Fieldwork, 2011

With educational level, none to primary level as the RC, the probability that the respondents with secondary level of education reusing wastewater is 0.1708 times lower than the RC (none to primary level) and was significant at $p < 0.1$. This indicates that this level of education has a lower probability of reusing wastewater, compared to the Reference Category in the selected communities.

With compound house type as RC, the probability that house types, detached, semi-detached, and apartment will reuse wastewater is 0.1510 times, 0.0511times and 0.1016 times lower than the RC (compound). This indicates that, these house types have a lower probability of reusing wastewater as compared to their counterpart in the compound house type in the selected communities even though they had significant values of 0.01, 0.002, and 0.009 respectively.

The compound house types were respondents in the low-income areas like Teshie with limited resources. They therefore had fewer and cheap options of coping with water stresses, like rainwater harvesting and therefore embraced any available option they could afford, hence wastewater reuse fits into their demands.

Table 6. 8: Multivariate correlates of demographic characteristics and wastewater reuse: Model 3

Predictable variables	Wastewater reuse		
	Odd ratio	Z- value	P-value
Occupation			
Farming/Artisan	RC		
Trading	12.5049*	1.94	0.052
Civil servant	2.0309	0.61	0.543
Self employed	4.5421	1.38	0.166
Other (Students/pensioners)	5.3683	1.42	0.157
Quantity of Water Used (l/c/d)			
Less than 100litres	RC		
>100 but<200litres	3.9637**	2.36	0.018
200-300litres	7.6975**	2.34	0.019
> 300litres	0.4214	-1.04	0.299
Cost of Waste Disposal			
31-60	RC		
61-90	0.5406	-0.54	0.589
91-120	0.8301	-0.16	0.875
121-150	4.6870	0.95	0.340
No cost	0.9405	-0.06	0.949

*** indicates significant at $p < 0.01$, **indicates significant at $p < 0.05$ and *indicates significant at $p < 0.1$

Source: Fieldwork, 2011

Occupation (trading) was significant at $p < 0.1$ and have a 12.5049 (OR = 12.5049) odd ratio for wastewater reuse compared to the reference category (Farming/Artisan). The significance of the responses could be tied to the income status of the respondents who were mostly found in Teshie.

Quantity of water use was a significant predictor of wastewater reuse. With the RC represented as 'less than 100litres' of water, the probability that respondents using >100 but <200litres of water and 200-300litres of water had 3.9637 times and 7.6975 times probability of reusing wastewater as compared to the reference category (Less than 100litres). This means that the probability of these groups reusing wastewater is higher than the reference category.

The respondents of the reference category were respondents in Ashale Botwe and Teshie, who used less water for their household purposes hence they embraced reuse of water more than any of the other high quantity of water consumers in Dansoman and East Legon.

In sum, although majority of respondents in all study localities accepted wastewater reuse, the specific groups who actually fell in the significant bracket are to be the focus of any follow-ups on wastewater reuse.

6.5 Chapter Summary

The focus of this chapter was to explore the extent to which wastewater was being used informally in households. Responses gathered from the field showed that majority of people representing about 84% had knowledge about wastewater reuse, but chi square results show that knowledge of reuse was not significant amongst all four localities. This was further interpreted to

mean that majority of the respondents were generally aware of the existence of wastewater reuse irrespective of locality, socio-economic status or education. There was also a very high usage of the resource (80%) in all sampled localities. However, reuse was highest in low income and water deprived areas to middle-income areas, than the high-income groups like East Legon: Teshie, 86.7%; Ashale Botwe, 91.67%, Dansoman Estates, 81.7%; and East Legon, 60%. Laundry wastewater (80%) was found to be the most common source of wastewater. The others were bath (20.4%), sink (2.5%) and other sources of wastewater (4.2%). Finally, multivariate analysis showed that marital status, age, house type and educational level were some of the significant predictors of wastewater reuse.

CHAPTER 7: PERCEPTION AND ACCEPTABILITY OF MODERN WATER REUSE TECHNOLOGIES

7.1 Introduction

Water can be a limited resource in an expanding global economy and population. Many water resource professionals believe that reclaiming water after it is treated in a modern wastewater treatment plant is an important but underutilized element of sustainable water resource management (Hartley, 2005). As a result, much attention has been put on pursuing it in terms of its technology and the role culture plays in its development. However, according to Po et al. (2004), cited in Mekala *et. al.* (2008), there is obvious lack of social research in understanding the basis of public perceptions of water use and the psychological factors governing their decision-making processes.

According to Bruvold, (1998), people generally favour multiple reuses that promote water conservation, provide environmental protection benefits, protects human health, and cost effectively treats and distributes a valuable and limited resource. However, as the water options become more tangible to people with specific proposed projects in their communities and the likelihood of human contact increasing, attitudes change and the public's support wanes.

As already mentioned, the potential applications for wastewater reuse worldwide include landscape irrigation, non-potable urban use and the most challenging target, potable reuse. Lu et.al (2003) however note that, notwithstanding the use, wastewater reclamation and reuse planning requires the support of whole society including public recognition, financial aid, and legislation through government. For instance, Haller, (1995) cited in Lu et.al., (2003) emphasizes that, municipal waste water contains many chemicals, which present known or potential health risks if ingested. Hence, whether wastewater reuse is appropriate or not depends upon careful

economic considerations, potential uses for reclaimed water, stringency of wastewater requirement and public policy wherein the desire to conserve rather than develop available resources may override economic and public health considerations (Lu et.al., 2003).

7.2 Socio-Cultural and Public Health Concerns in Water Reuse

In the light of the above statements, several responses were derived from the field on diverse issues of perception. The first one was respondents' choice of wastewater either for potable use, non-potable use or both. Table 7.1 revealed that 76.2% of respondents preferred reuse for non-potable uses only. They shunned potable reuse because, they considered it unsafe, 'dirty' and against their values. These finding corroborate works by Hartley (2005) in the United State of America, who found out that survey and case study research since the 1970s shows that the public in many of these states supports the general concept of using reclaimed water but has been supportive of non-potable reuse initiatives only.

On the issue of sustainability, respondents were asked if they would be willing to reuse water if it would solve their water problems. Majority of responses were definite (75%) whilst another 21% were positive in their opinion, but conditional. Only 3.3% said 'no, definitely' to the issue (Table 7.1). Again, whilst majority was for reuse options for non-potable uses, a whopping 79.6% would prefer reuse from their own sources (Table 7.1). Their argument was that, they do not know the sources or condition of their neighbours wastewater and therefore would prefer to use their own to be on the 'safe side'. A respondent in Teshie also recounts;

“Ahhh, how can I use wastewater from someone else's house? I don't know what they use their water for so no!. Spiritually, it is not even healthy. I prefer to use my own wastewater (Comfort, August, 2011)”.

Another in Dansoman Estates said;

“No, because I do not know the source and extent of pollution of other people’s waste, but I know the extent of pollution in mine so I will know what to use it for. I see myself frowning at someone else’s waste, hmm! (Eva Abbey, August, 2011)”.

In the UK, a study in 2000 corroborated the type of “source” as a factor that influences reuse. It found people more willing to use recycled water from their own wastewater than from second parties or a common public source (Jeffery, 2001).

Table 7. 1: Factors Influencing Willingness of Respondents to Use Wastewater

Willingness to Reuse	Yes, definitely	Yes, perhaps	Not really	No, definitely	Total
For non potable uses only	(76.2%)	(18.2%)	(0.8%)	(4.2%)	100%
Solve water problem	(75.0%)	(21.7%)	-	(3.3%)	100%
Own recycled wastewater	(79.6%)	(17.1%)	-	(3.3%)	100%
From a centralized (shared) system	(21.7%)	(25.0%)	(6.7%)	(46.7%)	100%
Shorter acquisition distance than potable water	(39.6%)	(40.0%)	(10.0%)	(10.4%)	100%
Buy agricultural products	(92.9%)	-	-	(7.1%)	100%

Source: Fieldwork, 2011

Other variables exploited in the localities were distance travelled to acquire potable water in comparison to wastewater. The data revealed that, majority of respondents would patronize the closer resource, provided its intended usage is met. Accordingly, distance has always been a problem in the acquisition of potable water for agriculture and sometimes for some domestic uses, like toilet flushing. This meant that, whichever resource was closest, they would patronize it, be it wastewater or potable water.

Lastly, respondent's willingness to buy agricultural products watered with wastewater was explored (Table 7.1). A high proportion (92.9%) of the total sample was actually willing to patronize such produce. They were of the opinion that, most of the vegetable farms in urban Accra were already practicing water reuse. The challenge was that, they did not conform to the health safety guidelines by Environmental Protection Agency (EPA) and Department of Parks and Garden. Therefore, if reuse is made legal and its implementation controlled, such agricultural produce will be safer for consumption. The World Health Organization (2006) notes that, wastewater is an important source of water and nutrients for many farmers in arid and semi-arid climates. Sometimes it is the only water source available for agriculture. When wastewater is well managed, it helps to recycle nutrients and water by taking advantage of the soil's capacity to naturally remove contamination (WHO, 2006) and therefore diminishes the cost and use of fertilizers (Hijazi and AL-Sharif (2010). Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water bodies.

7.3 Health Implication of Reusing Wastewater

Another variable that was critical to the study was the health implications of wastewater reuse. The presence of pathogens and chemicals in wastewater pose potential risks of human exposure during potable or non-potable water reuse processes, which may undermine the benefits obtained with more efficient utilization of water resources. Protecting public health is achieved by reducing pathogenic micro-organisms, controlling the quantities of different chemical constituents within the treated wastewater, and limiting the public's exposure to the treated wastewater through physical contact, inhalation and ingestion (Jacangelo, 2009) since it is not for potable uses. Adewumi *et al* (2010), in their research in Cape Town, South Africa, found out

that some centralized wastewater treatment plants only supply large institutional users with treated wastewater for primarily non-drinking water requirements. This thus reduces the potential risks to public health, as domestic consumers are not connected to the treated wastewater pipe networks.

Table 7. 2: Reuse for Potable and Non-Potable uses

Reuse Purpose	Yes responses
Potable purposes	0.4%
Non potable purposes	99.6%
Total	100.0%

Source: Fieldwork, 2011

Opinion of respondents was assessed against this background. As indicated in Table 7.2, majority (99.6%) were of the opinion that it was only healthy to use wastewater for non-potable uses only and would only use the resource if it does not pose any health threat to them.

7.4 Wastewater Reuse Potential under Alternative Prices

This section explores how much respondents were willing to pay for wastewater compared to potable water. This was to find out how committed they will be to the concept of reuse. Research by Khouzam, (2003) argues that the high cost of the utilization of non-conventional water resources especially wastewater could be economically justified. Beside the direct benefits of increasing water supply and saving the environment from the damaging effect of dumping wastewater, it supports sustainable development. Vigneswaran and Sundaravadivel (2006) also note that, costs associated with water supply or wastewater disposal may make reuse of wastewater an attractive option. In East Legon, an educated woman who embraced the idea of reuse expressed sadly;

“A few days ago, I felt sad that all the wastewater from my septic tank was collected only to be thrown away at great cost. I wished that I had a means of reusing that water for my lawns without generating foul smell. Your work is a great step in the right direction and let me know if you can assist me in some reuse options (Shika, August, 2011)”.

Figure 7.1 shows income groups put into gradations of below 200, 200-500, 501-1000, 1001-1500, and beyond 1500 Ghana cedis. These were related to proposed cost ranges of wastewater (no cost; half; one-tenth; one-third; and indifferent¹¹) in comparison to potable water.

Respondents in study localities were therefore asked how much they would be willing to pay for wastewater as against potable water. Figure 7.1 shows varied responses.

¹¹ Indifferent' was interpreted to mean any amount of money. Respondents in that category were willing to pay whatever amount presented to them

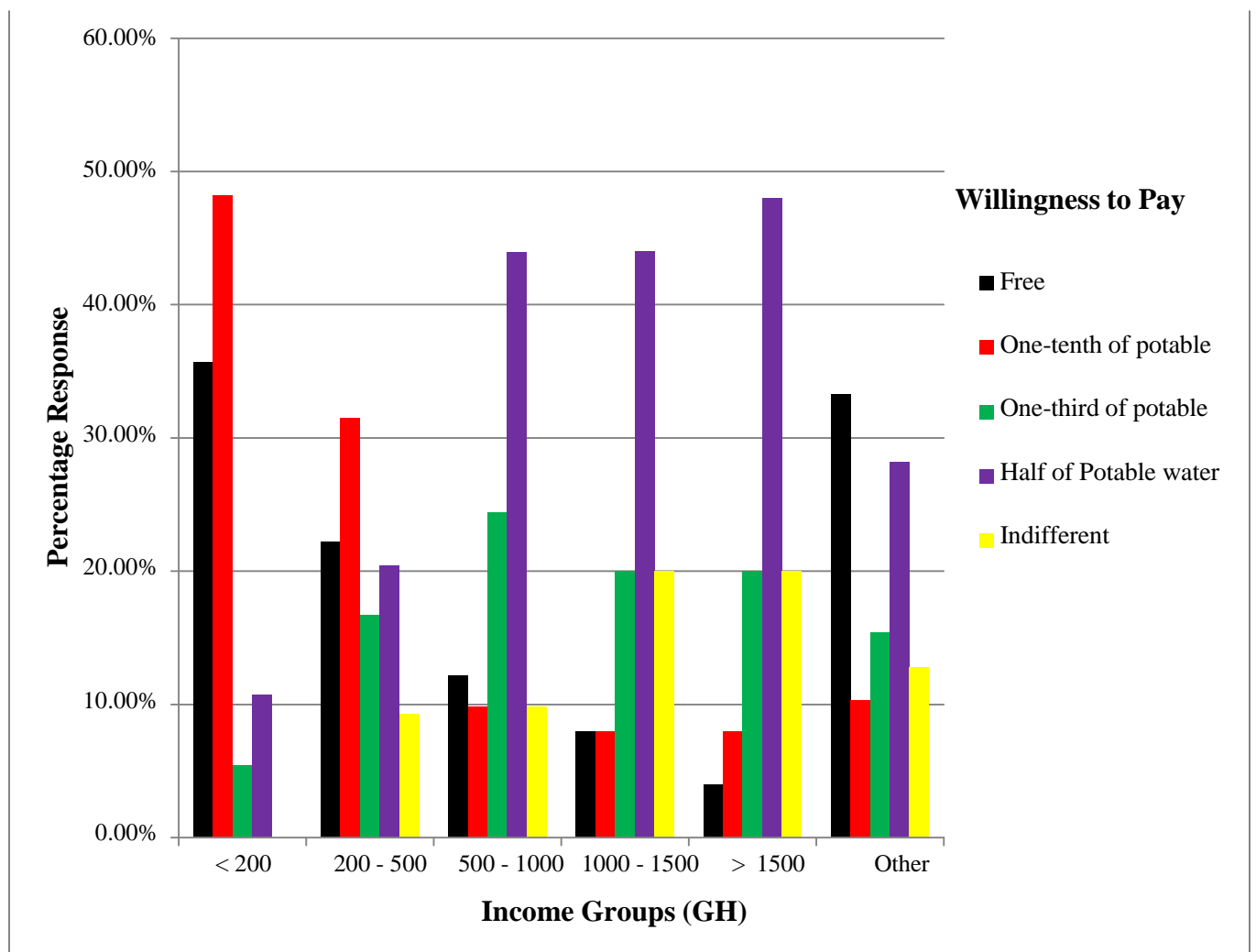


Figure 7. 1: Relationship between Income and Willingness to Pay for Wastewater

Source: Fieldwork, 2011

Figure 7.1 shows that a majority of respondents of relatively low-income status (< GH¢200) were willing to pay one-tenth (1/10) of what they pay for potable water. Alternatively, they would want it for free or at no cost. On the other hand, respondents in high socio-economic brackets, that is, East Legon, firstly, were willing to pay half or higher of what they pay for potable water. Their second option was to pay one-third of what they usually pay for potable water. However, respondents in the “indifferent” category were willing to pay whatever amount presented to them representing their third option. A few respondents of such high-income group

however would want it at no cost. Overall, respondents were willing to pay less than cost of potable water, with the higher income groups willing to pay more than the lower income groups; hence income of respondents bore a direct relation to cost of purchase of wastewater. These findings confirm work in Melbourne by Marks et al. (2002) cited in Mekala et al. (2008) who found that the majority of people expected to pay less for using recycled water because of the water quality and restrictions on the people's use of this resource. Nevertheless, focus group interviews conducted by Kaercher et al. (2003) further indicated that lower price was necessary to encourage acceptance of the resource. Therefore, if the price was set too close to the price of potable water, uncertain users will tend to use potable water for all purposes 'to be on the safe side'. The conclusions from the fieldwork were therefore consistent with these other findings.

7.5 Decentralized versus Centralized Wastewater Treatment Systems

Wastewater can be reused through three major sources. They are; released treated wastewater within factories after meeting the quality standard requirement as is the case with large enterprises which have their own wastewater treatment facilities (such treated water integrates into the natural water bodies and is used by downstream users as fresh water supply). Secondly, the central wastewater treatment plants and thirdly the decentralized on site wastewater treatment facilities (Yang and Abbaspour, 2007).

According to Adu-Ahyiah and Anku (2004), in Ghana and other developing countries, especially in sub-Saharan Africa, efficient collection and treatment of wastewater to meet EU standard is unrealistic. Conventional wastewater treatment plant cannot operate at their full capacities due to improper sewer networks to meet the plants' capacities. On the other hand, a decentralized system looks more realistic as an alternative. Yang and Abbaspour (2007) note that decentralized wastewater treatment facilities are drawing increasing attention in recent years and that in

Beijing in China, it has been the preferred option for newly developed residential buildings to build on-site wastewater reuse facilities. The reasons are that, decentralized wastewater treatment plants are easy to manage, cost effective and have high public acceptance than centralized wastewater treatment plants. Consequently, decentralized wastewater management may be defined as the collection, treatment, and disposal or reuse of wastewater from individual homes, clusters of homes, isolated communities, industries or industrial facilities, as well as from portions of existing communities at or near the point of waste generation (Crites and Tchobanoglous, 1998).

From in-depth interviews with the Assemblyman in Teshie on the type of reuse system suited for their communities, much preference was for reuse at the decentralized level. This view was shared during the questionnaire survey in all the communities; East Legon, Dansoman Estates, Teshie and Ashale Botwe (68.3%, 81.7%, 83.3%, and 81.7% respectively). However, they were of the view that a few centralized systems could be put up for communal purposes like lawn watering and urban agriculture. In addition, residents living in gated communities and estates could make use of communal wastewater for purposes like flushing toilets properly if it is differentiated from potable water. Teshie respondents stressed that, people in high socio-economic communities waste too much water so reuse will be in the right direction to help other areas who hardly have water flowing through their taps.

Table 7. 3: Willingness to Support a Decentralized Wastewater Treatment Plant Initiative for the Communities

Locality	Yes	No	Total
East Legon	68.3%	31.7%	100.0%
Dansoman Estate	81.7%	18.3%	100.0%
Teshie	83.3%	16.7%	100.0%
Ashale Botwe	81.7%	18.3%	100.0%
Total	78.8%	21.2%	100.0%
$X^2 = 5.254$	P-Value= 0.154		

Source: Fieldwork, 2011

For such high socio-economic localities, advanced treatment facilities befitting their socio-economic status should be considered. Adu-Ahyiah and Anku (2004) posit that there are decentralized systems that combine new technology and advanced treatment methods to treat effluent to a high standard, making wastewater acceptable for reuse in gardens, for firefighting purposes and homes as well. The categories of systems available are the tank system, the pond system, the filter system (which is an improvement of the tank system) and the root zone system (Adu-Ahyiah and Anku, 2004). Nevertheless, chi square results show that willingness to support decentralized systems were not significant amongst all four localities. Chi square value of 0.154 revealed that the expected means were higher when tested at $p < 0.05$, hence no significant relationship exist between decentralized systems and the type of locality (Table 7.3).

7.6 Role of Governance

Governance is defined as the use of political power, policy initiatives and organizational capacity to manage society's affairs and challenges. The field of governance may vary from the international arena to the nation state and to the local community. Governments, the private sector and community organizations confront a range of challenging new governance issues. Governance deals with the structure and operations of government from local to

international levels but also involves the contributions to public management from non-governmental organizations, including community groups and private sector corporations and associations <http://www.polsis.uq.edu.au/materials/Brochures/GPPBrochure.pdf>.

A policy usually guides the functions of government thereby serving as a form of check in its activities. IWRM (2005) document describes a policy as often the starting point being a statement of intent. It further went on to explain that the essential difference in translating the policy to a strategy is that it seeks to meet certain goals through specific investments. In a strategy, the investment resources available and options to reach the goals have to be assessed and a programme devised for these resources to be spent in an equitable but at the same time economically efficient manner.

In the context of wastewater reuse, the World Health Organization (2006) document on *Policy and Regulatory Aspects for the Safe Use of Wastewater, Excreta and Greywater* provides the most comprehensive guidelines for developing national policies for wastewater reuse.

The WHO (2006) suggest that, in developing a national policy framework to facilitate the safe use of wastewater, excreta and grey water, it is important to define the objectives of the policies, assess the current policy environment, formulate new policies or adjust existing ones, and develop a national strategy. Presently, information on the existing or potential magnitude of wastewater in both absolute and relative terms for the different types of use provides a key to the type of policy formulation or adjustment that may be needed.

The WHO (2006) again suggests that, policy appraisal for wastewater use should take place from two perspectives: The perspective of the policy-maker, who will want to ensure that the national policies and associated legislation, institutional framework and regulations meet the wastewater

objectives; and that of the project manager, who will want to ensure that current and future waste use activities can comply, realistically, with all relevant national and local laws and regulations.

Significantly, and depending on local conditions, policies for the use of wastewater may be emphasized within the food security, public health or within the environmental protection policy framework. Whatever the case may be, for their *safe* use, effective links will have to be established with the national public health policy framework.

However, currently, Ghana does not have any policy on wastewater reuse. In Ghana's policy formulation process, the Water Vision for 2025 has the main objective to "*promote an efficient and effective management system and environmentally sound development of all water resources in Ghana*" (GWP, 2007; P9).

According to the policy document, for the nation to achieve the above objective and to respond to current priorities, it is important to adopt a holistic approach to water resources management and development. This includes adopting Integrated Water Resources Management (IWRM) to enhance sustainable management of water resources and provide appropriate decision support systems for evaluating competing uses of water. It must be emphasized that, embedded in the IWRM among other things is wastewater reuse, meaning that its framework has therefore been laid for its future development.

Up until 2012, none of the sector agencies has made any provision for the inclusion of wastewater reuse in its policies. The new development is currently geared towards rainwater harvesting as it is seen as a more realistic and acceptable option.

However, at the Third Ghana Water Forum (GWF- 3, 2011), just like many other fora that discusses issues of reuse for possible inclusion, the adoption of various forms of reuse was discussed. At one of such discussions, participants agreed that it is feasible to create wealth from wastewater for agricultural activities. This was revealed at the governance parallel session of the GWF-3 where participants benefitted from experience and research information sharing. Concerns were however raised about public awareness of reuse of wastewater and the possible health implications that may arise from contamination.

7.7 Chapter Summary

In general, this chapter assessed the perception of stakeholders on the economic, social and health implications of wastewater reuse in the sampled localities. Generally, respondents expressed willingness to reuse wastewater if it would help solve their water problems economically. However, emphasis was placed on reuse from their own sources (79.6) and for non-potable purposes only (76.2%). Further, 99.6% expressed that; these non-potable purposes should not affect their health. Value placed on the resource was also critical in determining willingness to reuse wastewater. Whereas low-income areas, who expressed the most desire for reuse, were willing to pay less or wanted to pay nothing for the resource, high income areas were willing to pay close to half of what they pay for potable water. This cost is in terms of chemicals for treating the wastewater and its infrastructural set-up. Lastly, both high and low- income areas expressed willingness to reuse wastewater at the decentralized level than centralized level because of better management.

CHAPTER 8

SUMMARY AND RECOMMENDATIONS

8.1 Introduction

This chapter concludes the research on water demand and supply pattern in GAMA and associated coping mechanisms in the face of water stresses. Issues discussed here include summary of the work, the conclusions drawn from the findings and the ultimate recommendations to influence policy direction on issues related to water provision.

8.2 Summary

This study sought to assess potable water demand and supply patterns at the household and municipal level in the GAMA. The main objective was to give a preview and then analyze the water situation in the study area as a basis for considerations of where wastewater reuse will be most feasible and can be exploited. In addition, the study examined existing informal arrangements that households undertake to cope with water stresses. This was based on the assumptions that households resort to various coping mechanisms but may be influenced by space and local conditions in the various urban and rural environments. Hence, the need to identify the unique circumstances that influence the various choices of adaptation.

Another very important coping mechanism that formed a significant part of the study was wastewater reuse including issues relating to how it was being used informally in households in the Ghanaian urban setting. The use of informal and advanced methods was also explored in order to assess all categories of stakeholders for its adoption.

Finally, the perception of stakeholders on the economic, social and health implications of wastewater reuse was assessed. This objective explored all the factors that impinged negatively or positively on reuse.

Results of the study indicate that the issue of inadequate water supply from GWCL cuts across all study localities in the GAMA as a whole. This was due to major infrastructural problems faced by the providers. As a result, it was difficult to meet the needs of all identified communities in the GAMA, including the higher socio-economic classes, especially the elite communities. The low income localities were more affected.

Since the problem was seen to cut across the entire GAMA, various coping mechanisms were adopted by all residents. The type of coping mechanism adopted also bore a direct relation to the socio-economic status of the respondents. The types identified in the study included the use of borehole and well water, rain water harvesting, tanker and vendor service, neighbour water and wastewater reuse. Significantly, high-income areas resorted to borehole water and tanker service and rainwater respectively, whereas low-income areas resorted mainly to well water, neighbour and rainwater harvesting concurrently.

In terms of preference, rainwater was the cheapest source of water and its usage cut across the entire study area, although it was not the preferred choice due to its unreliability. Tanker service, according to responses, was the most preferred choice subject to the cost. Respondents across board considered water from tanker service safer to use since it was often provided from GWCL and was less likely to make them sick. High- income areas used tanker service mainly for household purposes whilst low-income areas retailed it for commercial purposes to generate additional income.

Despite the widespread use of wastewater worldwide, municipalities and water boards underestimate its value, and for policymakers, it is a non-issue (WHO, 2006). The lack of information and awareness both among producers and consumers about the inherent risks of wastewater use further compounds the problem. Difficulties faced in wastewater use worldwide relate to the non-availability of guidelines (Kaul et al., 2002:3). Compatibility of reclaimed water with its intended usage is an important consideration in developing a wastewater reuse system. Higher level uses, such as for irrigating public access lands (e.g. parks) and the cultivation of vegetables requires higher levels of treatment compared to lower level usage such as pasture maintenance, floriculture and agro-forestry irrigation.

Results of the study further indicated that majority of respondents embraced wastewater reuse. Awareness and knowledge of the phenomenon was relatively high. Those who were not reusing water had a higher propensity for reuse. Results of odd ratio (OR) of logistic regression for individual characteristics predicting respondents' use of wastewater in the study area revealed that many variables like age, marital status, religion, educational status and house type were statistically significant.

Generally, all respondents were willing to pay less for wastewater than they did for potable water because they consider it 'used' as is also supported by other researches like Marks et al. (2002); Kaercher et al. (2003) and Vigneswaran and Sundaravadivel (2006). However, high-income groups were willing to invest more for wastewater reuse than low-income groups. The conclusion derived from the analysis of reuse was its direct relation to income and wealth of the socio-economic classes.

In addition, majority of respondents (99.6%) were of the opinion that it was healthy to use wastewater for non-potable uses only, and another 97% would only use the resource if it does

not pose any health threat to them. There was also a 92.9% general willingness to purchase agricultural products watered with wastewater. Finally, there was high preference for reuse at the decentralized level, especially because of the well-known problems of water distribution using centralized systems. Abundant documentation from current studies shows that decentralized systems are more efficient, save resources, localized, community-oriented and sustainable (Adu- Ahyiah and Anku, 2004).

8.3 Conclusion

Sustainability means development that meets the needs of the present without compromising the ability of the future generations to meet their own needs (Brundtland Commission Report,1987).

This is what this research sought to achieve. Studies by Escobar and Shafer (2010) in a research on Sustainable water for the future stated that;

‘...if we are to achieve a sustainable water system, we need to make better use of existing water supplies, we need to identify new ways to create drinking water from non-potable sources, and we need to develop technologies that reuse the water that we have already extracted’.

This is why the research concluded that, the challenges of uneven water supply in the GAMA have become widespread. Consequently, approaches for solving them must recognize and factor into them the unique spatial variability of the problem to bring about equitable and sustainable distribution of water resources for all stakeholders.

Owing to the shortfall in supply, customer satisfaction ranges from excellent to very poor depending on location of the customer. In the course of balancing demand and supply, GWCL has embarked on a rationing programme, which is also negatively affecting socio-economic activities. For the system to work effectively and efficiently and to overcome the present water crisis, efforts are being made by GWCL to bridge the gap between the supply and demand through several interventions. The current water situation which follows the *first basic law of supply and demand* states that “if demand increases and supply remains unchanged, a shortage

occurs leading to a higher equilibrium price, making it impossible for consumers to afford’.

This situation is going to continue in GAMA if efforts by the government are not made to balance demand and supply, by varying the variables until the needed equilibrium (in terms of price and quality) is achieved in water service delivery.

One of the identified measures to help solve the problem of shortage in supply is water coping mechanisms. Two water coping measures, *supply measures* made up of rainwater, borehole/well water, wastewater reuse, tanker, vendor and neighbour water use and *demand management measures* like the use of water holding facilities were seen as important adaptation mechanisms to guarantee water supply. These findings also corroborate other studies like Lawton et.al. (2009), whose framework concentrated on sustainable water management.

Again, the quest to find a second and/or sustainable solution to the increasing problems of urban water supply especially in this era of population explosion was demonstrated in this research. This is wastewater reuse. Not only is wastewater reuse rapidly emerging as a strategic option, it is more environmentally friendly, sustainable and complements the other sources of water such as rain harvesting, borehole water and pipe-borne water which are in use in the GAMA.

Without doubt, wastewater reuse is widely known and used by a majority of the respondents. However, its adoption is influenced greatly by socio-economic status of residents and availability of other preferred options. Further, its implementation as a policy option, according to the respondents should be decentralized at the individual and community levels with appropriate government support. Thus, according to Escobar and Shafer (2010), it is incumbent upon scientists and engineers to continue to develop new technologies that make better use of our scarce resources so that resources can be distributed more equitably and world’s population can continue to flourish.

8.4 Recommendations

On the basis of the outcome of the study, some recommendations are made to help bridge the gap in knowledge and adoption of reuse options and other water coping mechanisms for the mutual benefit of all water stakeholders. The general premise is that wastewater use for a variety of purposes, including agriculture, has been a common phenomenon in a number of water scarce developing countries for more than a century now. To address the problem in a holistic manner, there are therefore lessons and experiences to be learnt in terms of its advocacy, concept, practice, and the technology to tackle issues of perception of people regarding wastewater reuse.

- i. It is therefore recommended that, these can be achieved through education and awareness programmes on willingness to reuse and the eventual protection of the environment. Any decision to develop a national policy on wastewater reuse should use updated evidence concerning health impacts, environmental concerns, food security and public perceptions associated with the use of wastewater, in any form to develop rational and cost-effective policies for protecting public health and maximizing the beneficial use of natural resources.
- ii. Political will and institutional support are essential to make wastewater a safe asset for people in developing countries. The perspective of the policy-maker, who will want to ensure that the national policies and associated legislation, institutional framework and regulations meet the wastewater objectives; and that of the project manager, who will want to ensure that current and future waste use activities can comply, realistically, with all relevant national and local laws and regulations should be developed.

- iii. There is the need for further research on reuse at household and community level and other sectors, including particularly industry and agriculture.

- iv. Finally, there is need for extensive research into rainwater harvesting that will work alongside wastewater reuse thereby solving the issue of water deficit from both the supply side and demand side.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE FOR HOUSEHOLDS

Department of Geography and Resource Development University of Ghana - Legon

Assessing Existing Water Demand and Supply Patterns and Reuse Options as Additional Sources of Water in Greater Accra Metropolitan Area (GAMA)

This questionnaire is in support of a study for the award of MPhil Degree in Geography and Resource Devt. The result is purely academic and will be treated with utmost confidentiality

Number.....

Date

SECTION A: PERSONAL DATA

1. Community:

1. a. East Legon	[]	b. Dansoman Estates	[]
2. c. Teshie	[]	d. Ashaley Botwe	[]
2. Ethnicity

a. Ga-Adangbe	[]	b. Akan	[]	c. Ewe	[]
d. Mole-Dagbani	[]	e. Other.....			
3. Sex:

a. Male	[]	b. Female	[]
---------	-----	-----------	-----
4. Age (in years):
5. Marital Status:

a. Single	[]	b. Married	[]	c. Consensual Union	[]
d. Separated	[]	e. Divorced	[]	f. Widowed	[]
6. Religion

a. Christian	[]	b. Muslim	[]	c. Traditional	[]	d. Other
--------------	-----	-----------	-----	----------------	-----	----------------
7. What is your highest educational attainment?

a. None	[]	b. Non-Formal Edu.	[]	c. Primary	[]	d. Middle/JSS	[]
e. Secondary	[]	f. Tertiary	[]	g. Other (specify) []			
8. What is your main occupation?

a. Farming/Fishing	[]	b. Trading	[]	c. Civil/Public Servant	[]
d. Artisan	[]	e. Self employed [] f. Other			
9. Are you engaged in any other income earning activity?

a. Yes	[]	b. No	[]
--------	-----	-------	-----
10. If yes, what is it?

11. How much on average do you earn in a month?
 a. < Gh¢ 200 [] b. Gh¢ 200 - 500 [] c. Gh¢ 500 - 1000 []
 d. Gh¢ 1000 - 1500 [] e. > Gh¢ 1500 [] f. Other.....
12. What house type do you live in?
 a. Compound [] b. Detached []
 c. Semi-Detached [] d. Apartment [] e. Other.....
13. Tenancy Arrangement
 a. Landlord/landlady [] b. Rent [] c. Caretaker [] d. Free Co-habitation []
 e. State owned [] f. Self owned
14. Household Size:
15. Which type of toilet facility do you have in your house?
 a. Water closet [] b. Pit latrine [] c. Bucket []
 d. Public toilet [] e. Other

B. POTABLE WATER DEMAND AND SUPPLY CHARACTERISTICS

B1: SUPPLY

16. Are you connected to Ghana Water Company Limited (GWCL) distribution network?
 a. Yes [] b. No []
17. Do you have a water meter?
 a. Yes [] b. No []
18. If yes, do you receive your bills regularly?
 a. Yes [] b. No []
19. How much do you pay for pipe borne water in a month

20. How many times in a week do you receive water supply
 a. Everyday [] b. 5 -6 times [] c. 3 – 4 times []
 d. 1 -2 times [] e. irregular [] f. none []
21. What will you say about the quality of the water that you get from GWCL?
 a. Good [] b. Salty [] c. Coloured [] d. Bad odour []
 e. Has some particles inside [] f. Other
22. Do you boil your water from GWCL before use? If
 a. Yes [] why
- b. No [] why
23. Which of the following categories of water do you drink?
 a. Pipe-water [] b. Boiled water [] c. Sachet water []
 d. Bottled water [] e. Other
24. Do you think it is important to pay for water?
 a. Yes, definitely [] b. Yes, perhaps [] c. Not really []
 d. No, definitely [] e. Don't Know []

25. Do you think the amount you pay for water is enough?
 a. Yes, definitely [] b. Yes, perhaps [] c. Not really []
 d. No, definitely [] e. Don't Know []
26. Are you willing to pay more for piped water if the current service is improved?
 a. Yes, definitely [] b. Yes, perhaps [] c. Neutral []
 d. No, not really [] e. No, definitely []
 f. Don't Know []
27. Rank in order of highest monthly expenditure (**Rank from 1st to 5th**) whereby 1 is the highest expenditure and 5 is the least expenditure.
 Water [] Electricity [] Accommodation [] Food [] Entertainment []
 Other.....

B2: DEMAND

28. What is the estimated total quantity of pipe-borne water used by your household per day? (20 litres = 1 "Kuffour" gallon)
 a. Less than 50 litres [] b. 50-100 litres [] c. Over 100 but less than 200 litres []
 d. Between 200-300 litres [] e. 301-400 litres [] f. More than 400 litres []
 g. Other
29. Are you satisfied with the level of water service provided by GWCL in your community?
 a. Yes, definitely [] b. Yes, perhaps [] c. Neutral []
 d. No, not really [] e. No, definitely [] f. Don't Know []
30. If not, what problems are you experiencing with the service?
 a. Leaking pipes [] b. Days without water [] c. Poor water quality []
 d. No water supply [] e. Illegal connection [] f. Other.....
31. Do you have any of these in your home?
 a. Lawn [] b. Garden [] c. Trees []
32. If yes, which of them do you water?
 a. Lawn [] b. Garden [] c. Trees [] d. None []
33. Do you take measures to reduce water use in the above activities?
 a. Yes [] b. No []

*For those who get water supply by other means, see section C

Causes of water problems	Major cause	Minor cause	Not a cause	Don't Know
i. Illegal connections				
ii. GWCL lack technical expertise to handle the pipe network				
iii. Tanker owners arrange with the GWCL staff to limit water supply				

- iv. Frequently broken down pipe lines
- v. Inadequate pipe lines to support fast expansion of township
- vi. Unplanned township/community
- vii. Electric power outage problems
- viii. Other (Specify)

47. Are there seasonal differences (rainy or dry) in water availability to your community?

a. Yes []

b. No []

c. Don't know []

48. Have you ever heard of climate change?

49. Do you think climate change can affect water supply?

a. Yes []

b. No []

50. If yes, how can it affect water supply

.....

.....

D WASTEWATER REUSE AND AWARENESS

51. Do you have any knowledge of wastewater reuse?

a. Yes

[]

b. No

[]

52. Do you reuse any form of your wastewater?

a. Yes

[]

b. No

[]

53. If yes to 52, do you reuse your wastewater from any of the following sources?

Rank in order of highest reuse whereby 1 is the highest reuse and 5 is the least reuse

Bath Sinks Laundry Sewerage Others (specify)....

54. What kind of uses do you put reuse water to

.....

55. If no to 51-54, have you ever considered reusing water after using for household chores?

a. Yes [] b. No []

56. Please explain your choice of answer above

.....

57. If climate change were to affect water supply, will you be willing to use treated wastewater and why?

.....

58. What type of drainage system do you have in your house

a. Septic tank [] b. Soak-away [] c. Open gutters []
 d. Closed gutters [] e. No drainage system [] f. Others

59. Where is the final collection of liquid waste in your house?

.....

Would you be willing to reuse treated wastewater..... Yes, definitely Yes, perhaps Not really No, definitely Don't Know

60. if it is for non potable uses only					
61. if it helps solve water problem					
62. if it is your own recycled wastewater					

63. if it is from a centralized system (shared)

64. if it is in close proximity than potable water

75. Would you be willing to reuse wastewater if it does not pose any health threat to you?

76. Would you feel comfortable to buy agricultural products that use treated wastewater? a.

Yes [] b. No []

77. Give reasons for your answer.....

D3: COST

78. Do you incur any cost disposing off your wastewater?

Yes [] No []

79. If yes, how much does it cost?

80. Will you be willing to use recycled wastewater if it is made cheaper than potable water?

Yes [] No []

81. How much will you be willing to pay for recycled water?

E. WAY FORWARD AND MODERN METHODS

82. Have you had or heard of any negative incidence associated with using wastewater

a. Yes [] b. No []

83. If yes to 81, please explain

84. Would you visit a hotel or commercial centre if you knew they use treated wastewater for non-potables purposes?

a. Yes [] b. No []

85. Have you heard of any campaign that encourages treated wastewater reuse

a. Yes [] b. No []

86. If yes to 84, where did you hear it.....

87. Do you think wastewater reuse can be considered as an option to augment the current water shortage in some communities in Accra?

a. Yes [] b. No []

88. Give reasons.....

89. Would you support an initiative that encourages fitted modern equipments for wastewater recycling in your home?

a. Yes [] b. No []

90. Would you support a decentralized wastewater treatment plant initiative for this community?

a. Yes b. No

91. Do you think Ghana should adopt wastewater treatment as additional option for sustainable water management in urban areas? Give reasons

.....
.....

92. Do you think water supply, operation and maintenance should be decentralized, and handled by private operators?

a. Yes b. No Don't Know

THANK YOU

APPENDIX 2

DEPARTMENT OF GEOGRAPHY AND RESOURCE DEVELOPMENT
UNIVERSITY OF GHANA - LEGON

WATER PROVIDERS**Assessing Existing Water Demand and Supply Patterns and Reuse Options as Additional Sources of Water in Greater Accra Metropolitan Area (GAMA)**

This questionnaire is in support of a study for the award of MPhil Degree in Geography and Resource Devt. The result is purely academic and will be treated with utmost confidentiality

Number

Company

1. What is your source of raw water for treatment at your treatment plant? Weija/ Kpong
2. Is this source reliable?
3. What is the daily production of water in Accra; what percent is kpong/weija
4. How many households 'of a certain total' are connected to your water network
5. What is the demand per day / per year
6. Do you meet the demand of your customers
7. Are there days when you don't meet your regular/ scheduled supply
8. If yes to 7, what accounts for this problem
9. What is the main idea behind rationing
10. Is there any area that is not affected by the water rationing schedule
11. If yes why aren't all customers supplied regularly
12. Do you have losses due to transmission and why
13. If yes what is the quantity/volume of loss water
14. If these losses are minimized/eliminated, will there be sufficient water for regular supply?
15. What interventions have you put in place to provide regular supply to customers?

16. How effective are these interventions
17. Do you receive regular payment from your customers?
18. Are your customers satisfied with your services
19. If no, is that a reason for the inability to provide regular water supply
20. Have you ever embarked on any sensitization exercise to educate your customers on good ways of managing potable water
21. If yes, what are some of these water management strategies
22. What form(s) of medium do you use
23. What is your view on wastewater reuse
24. Do you have a policy on wastewater reuse
25. Do you think Ghana will benefit from wastewater reuse as an alternative
26. What challenges are you likely to face if you explore this option
27. Has there been any pilot project in the past to explore this option?
28. Does GWCL have the capacity to handle a wastewater reuse plant
29. Has GWCL explored other sources of water apart from surface water
30. If yes, what considerations went into this option and how viable has it been
31. Is the current water situation going to change soon?
32. What is the way forward?

THANK YOU

APPENDIX 3

GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA (ATMA)

ACCRA EAST - A

AREA_NAMES	No. Of Days	Days of Flow
Teshie Nungua Est.	2	Wednesday, Sunday
Ablekuma		
Teshie Sea Lady	1	Saturday
Yomo Specs	1	Sunday
Akosombo 1-4 Area	1	Saturday
La T-Junc.	5	Monday, Tuesday, Thursday, Friday, Saturday
South La	2	Saturday, Sunday
La Palmwine Junc.	5	Monday, Tuesday, Thursday, Friday, Saturday
South Labadi Est.	2	Saturday, Sunday
Cantonments	7	Monday - Sunday
North Labadi Est.	2	Saturday, Sunday
La	5	Monday, Tuesday, Thursday, Friday, Saturday
Teshie		
Kpeshie	5	Monday, Tuesday, Thursday, Friday, Saturday
East Airport Residential Area	7	Monday - Sunday
Light Industrial Area	6	Monday, Tuesday, Thursday, Friday, Saturday
Batsonaa	2	Wednesday, Saturday, Sunday
Agbleshia	5	Monday, Tuesday, Thursday, Friday, Saturday
Mangoase	1	Sunday
Kpeshie Lagoon	2	Monday, Saturday
Nyaniba Est.		
AirPort City	7	Monday - Sunday
Apapa	5	Monday, Tuesday, Thursday, Saturday, Sunday
Labone Est.	2	Saturday, Sunday
La Tse Addo	4	Monday, Thursday, Friday, Saturday
Teshie Rasta	2	Monday, Saturday
Teshie Camp 2	1	Saturday
Teshie La Scala	1	
Teshie Old Town	1	Sunday
Teshie Zongo	2	Wednesday, Saturday
Burma Camp	5	Monday, Tuesday, Thursday, Friday, Saturday
Airport	7	Monday - Sunday (low pressure)
Sutsumunor	2	Saturday, Sunday (low pressure)
GREDA Est.	1	Wednesday
Nungua Old Town	1	Sunday, Saturday
Comm 15	2	Wednesday, Saturday, Sunday
Adosona Area		
Nungua Barrier	3	Wednesday, Saturday, Sunday
Composite Plant	1	Wednesday
Nungua Buade	3	Wednesday, Saturday, Sunday
Tsui Bleo	1	Wednesday
Naatrojor Area	1	Saturday
Adjor man Area	1	Wednesday
Okpoi Gonno Area	5	Monday, Tuesday, Thursday, Friday, Saturday
Manet Court Est.	5	Monday, Tuesday, Thursday, Friday, Saturday
Manet Ville Est.	5	Monday, Tuesday, Thursday, Friday, Saturday
Regimanuel Est.	5	Monday, Tuesday, Thursday, Friday, Saturday
Martey Tsuru Area	5	Monday, Tuesday, Thursday, Friday, Saturday

APPENDIX

3b

GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

ACCRA EAST DISTRICT - I

AREA_NAMES	NO OF DAYS	DAYS OF FLOW
Teshie Nungua Est.	Two days	Sat & Sunday
Abetwina	Not in the district	
Teshie Sea Lady	One day	Wed.
Komo Spect.	Two days	Sat & Sun
Abanorkor J & K Area	Three days	Wed; Sat & Sundays
Abanorkor	Five days	Mon, Wed - Saturdays
South La	Five days	Monday - Fridays
J.P. Line Junc.	Five days	Mon; Wed - Saturday
South Labadi Est.	Five days	Mon - Friday
Cantonment	Three days	Tues, Sat - Sunday
North Labadi Est.	Five days	Mon - Wed; Thur - Sat.
La	Three days	Tues, Sat - Sun
Teshie	Two days	Sat & Sunday
Kpeshie	Two days	Sat & Sundays
East Airport Residential Area	Five days	Mon; Tue, Thur - Sat.
Light Industrial Area	Five days	Mon; Tue, Thur - Sat.
Baatsoga	Three days	Tue; Friday & Sat
Agbleshie	Five days	Mon; Tue, Thur - Sat.
Mangoase	Two days	Sat & Sunday
Kpeshie Lagoon	Two days	Sat & Sunday
Nyaniba Est.	Not in the district	
AirPort City	Seven days	Mon - Sunday
Apapa	Four days	Tue - Sat
Labone Est.	Three days	Sat & Sundays Mon.
La Tse Adia	Two days	Thur & Friday
Teshie Rasta	Three days	Sat; Sunday & Mon.
Teshie Camp 2	Two days	Sat & Sundays
Teshie La Scala	Two days	- do -
Teshie Old Town	Two days	- do -
Teshie Zongo	One day	Wednesdays
Burma Camp	Seven days	Monday - Sundays
Airport	Seven days	Monday - Sundays
Assumonor	One day	Wednesday
GREDA Est.	One day	- do -
Nungua Old Town	Two days	Sat, & Sundays
Comin 15	Three days	Wed, Sat, & Sun
Akosona Area	Three days	- do -
Nungua Barrier	Three days	- do -
Composite Plant	One day	Wednesdays
Nungua Buade	Four days	Wed, Thur, Sat & Sun
Tsu Bleo	One day	Wednesdays
Nastropu Area	One day	- do -
Adjoroman Area	One day	- do -
Oldon Gomo Area	Five days	Mon - Tue & Thur - Sat.
Moonlight Est.	Five days	- do -
Moonville Est	Five days	- do -

APPENDIX

3c

GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

ACCRA EAST DISTRICT - II

2

Regional Office
 Martey Tsugu Area
 Mot. Way Ind. Area
 Airportfills Est.

Five days
 Four days
 Five days
 Five days

Mon-Tue + Thur-Sat
 Tue-Sat
 Mon-Tue+Thur-Sat
 Mon-Tue+Thur-Sat

IMPORTANT PLACES

Christ The King Sch.
 Police Headquarters
 Labadi Beach Hotel
 La Palm Royal Hotel
 La Cemetery
 Int'l Trade Fair
 Home Touch Rest.
 Whittier Baracks
 Krobo Schools
 Kpeshie Police Station
 Kotoka Int'l Airport
 Nautical College
 MATS
 Labadi Beach
 J.B. Danquah Circle
 Police Hospital

Seven ~~the~~ days
 Seven days
 Five days
 Five days
 Five days
 Five days
 Six days

Mon - Sundays
 Mon - Sundays
 Mon, Wed - Sat.
 - do -
 - do -
 - do -
 Mon - Saturdays

Three days
 Three days
 Seven days
 Five days
 Five days
 Five days
 Seven days
 Seven days

Wed, Sat - Sundays
 Wed, Sat - Sun.
 Mon - Sundays
 Weds - Mondays
 Mon, Wed, Thur - Sat
 - do -
 Mon - Sunday
 Mon - Sunday

APPENDIX

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GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

29-06-2011

ACCRA NORTH EAST	AREA_NAMES	No. Of Days	Days of Flow
	Pokuase Exits Area	—	No water in Monday, Tue, Wed, Thu, Fri, Sat, Sun
	Amasaman	—	No distribution
	Atwuo Okuman	—	No distribution
	Madina Zongo	1	Thursdays
	Otuwa	—	No distribution
	Ashongman	1	Thursdays
	Abladzei	—	
	Pantang	1	Fridays
	Abokobi	—	CWSA
	Adenta SSHA FLATS	1	Sundays
	Oyarifa	—	
	Teiman	—	
	Ashale Botwe	2	Mondays/Tuesdays EOD
	Abotsiman	1	Wednesdays
	Akorakor	—	No distribution
	Oshiyie	—	4
	Amanfro	—	4
	Mamahuma	—	4
	Sesemi	—	4
	Nyamekurom	—	4
	Adjirigano69	5	Mond, Tue, Thurs, Fri, Sat EOD
	Tesa	5	do.
	East Legon Res. Area	1	Thursdays
	Shiashie	1	Saturdays
	Akpomang	—	No distribution
	Boi	—	4
	Otopram	—	4
	Dedekurom	—	4
	Bobomase	—	4
	Ogoha	—	4
	Quarters	—	4
	Television Transmitting Station	—	4
	Akoto	—	4
	Adusu	—	4
	Mayera	—	4
	Osofoman	—	4
	Katakpo	—	4
	Afiaman	—	4
	Ayesu	—	4
	Afibu	—	4
	Nsakyir	—	4
	Toman	—	4
	Shikponte	—	4
	Agriculture Station	—	4
	Sapeman	—	4
	Agbon No.1	—	4
	Pobi-Asaawa	—	4
	Nkuntunse	—	4

APPENDIX

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GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

Okplonglo	7	Sunly
La Bawaleshie	7	sunly
Adjirigano Village	7	Sunly
Adaman		
Ogbodzo	—	No flow.
26 Ogbodzo	—	do.
ACP Est.	7	Sunly
Manor Valley	2	Mon./Tues. EOW
Jogis Est.	5	Except Wed/Sunday
Trassaco Est.	5	do
Top King	5	do
Bedzin	2	Wed./Thurs. EOW
Dzen Ayor	3	Mon./Tues, Wed., EOW
Otanor	3	Thurs, Fri., Sat. EOW
Otinshi	1	Thursday EOW.
American House	2	Thursday./Fri. EOW.
East Legon Ext(Achorga)	1	Monday EOW.
Atraco	2	Tues. Thurs.
Atraco Down	2	do
Land Lord 8	2	do
Ogbojo Manet	—	No flow
East Legon (Asedi Peli)	1	Friday
La Bawaleshi	7	Sunly
Instrumentation	1	Thursday
Mpeasem	1	do
Legon Staff Village	2	Tues. & Thursday
Atomic Junc.	1	Thursday
New Road Rawlings Circle	1	Thursday
Fire Stone	1	Thursday
Madina Old Road	1	Wednesday
Libya Qtrs	1	Thursday
North Legon	1	do
Agbogba	1	do
West Adenta	1	Friday
East Adenta	2	Mon./Tues EOW
Nkwantanang	2	do
Aproteh Top	1	Saturday
Aproteh Down	1	Sunday
Frafraha	6	Except Thursday
Commando	1	Friday

ACCRA CENTRAL - B

AREA NAMES	No. Of Days	Days of Flow
Agbogloboshie	7	7
South Industrial Area	7	7
Asylum Down	7	7
Adabraka	7	7
West Ridge	7	7
North Rigde	7	7
Ringway Est.	7	7
Ussher Town	6	6
James Town	5	5
Korle Lagoon	7	7
Korle Dudor	5	5
Osu	5	5
East Ridge	7	7

APPENDIX

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GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

ACCRA NORTH		
AREA NAMES	Na. Of Days	Days of Flow
Kwabenya	2	2
Kokomlemle	7	7
Kanda Est.	7	7
Nima	4	4
Mamobi		
Kotobabi		
Accra New Town	4	4
Abelemkpe	7	7
Alajo	7	7
Dzorwulu	7	7
Roman Ridge	7	7
Airport Residential Area	7	7
North Dzorwulu	7	7
Kpehe	7	7
Abofu	7	7
Christian Village	6	6
Oko	6	6
Kissemán	6	6
Papao	6	6
Dome		
Pig Farm		
East Dzorwulu Residential Area	7	7
Legon	7	7
South Legon	7	7
West Legon Right Side	7	7
Haatso	6	6
Paraku Est.	6	6
Dome Transformer	3	3
Taifa	4	4
Regimanuel	2	2

APPENDIX

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GWCL Water Rationing Data for Greater Accra Metropolitan Area, GAMA(ATMA)

AKA - NORTH DISTRICT

AREA NAME	NO. OF DAYS	DAYS OF FLOW
HABISO	6	6
PARKKOU ESTATE	6	6
DOME PILLAR 2	3	3
DOME TRANSFORMAL	3	3
TAIFA TOWNSHIP	4	4
TAIFA SOUTH	2	2
TAIFA NORTH	2	2
GIMPA	6	6
ACHIMOTA SCHOOL	6	6
ACHIMOTA ABC	7	7
ACHIMOTA HEOPLAN	7	7
ATOMIC QUARTERS	7	7
DOME KABIT	6	6
CAPRICE	7	7
PARTS OF CIRCLE	7	7
MALLAM ASAH.	4	4
KAWUKUDI		
OKPOGLOH	7	7
DOME MARKET	7	7

Toiletfaci~1						
2	1.846427	1.352718	0.84	0.403	.4392688	7.761292
3	.2651299	.2539507	-1.39	0.166	.0405647	1.732883
Housetype1						
2	.1509586	.112894	-2.53	0.011	.0348569	.6537722
3	.0510641	.0480054	-3.16	0.002	.0080891	.322352
4	.1015505	.0882915	-2.63	0.009	.0184764	.5581433
Occupation1						
2	12.50487	16.28689	1.94	0.052	.9737282	160.5909
3	2.030852	2.364874	0.61	0.543	.2072414	19.90124
4	4.542094	4.964656	1.38	0.166	.5331696	38.69429
5	5.368301	6.370015	1.42	0.157	.5245693	54.93775
Quantitywa~1						
2	3.96373	2.313248	2.36	0.018	1.262814	12.44138
3	7.697541	6.71749	2.34	0.019	1.391635	42.57734
4	.421363	.3506501	-1.04	0.299	.0824713	2.15283
HowMuchCost1						
2	.54061	.6157992	-0.54	0.589	.0579823	5.040489
3	.830091	.9844005	-0.16	0.875	.0812251	8.483227
4	4.686953	7.593049	0.95	0.340	.1958441	112.1685
5	.9405162	.9092196	-0.06	0.949	.141413	6.25523
