ASSESSMENT OF URBAN POTABLE WATER AVAILABILITY AND ACCESSIBILITY IN KIGALI CITY, RWANDA

By

BIMENYIMANA Théoneste

Bsc. Geo/Env.Mgt. (NUR-Rwanda), PGCLTHE-Education (KIE-Rwanda)

REG N° : MEM/37095/121/DF

A Dissertation

Presented to the College of Higher Degrees and Research
In partial fulfillment of the requirements for award of
Master of Science degree in Environmental Management and Development of
Kampala International University, Uganda

December, 2013

DECLARATION

I, Théoneste BIMENYIMANA, declare that this thesis is my original work and all other sources of material used are duly acknowledged. This work has not been presented for a degree or any other academic award in any university or institution of higher learning.

Name : **Théoneste BIMENYIMANA**

Signature : ....

Date : 10th Dec. 2013

APPROVAL

I confirm that the work presented in this dissertation was carried out by the candidate under my supervision and is presented for examination with my approval.

Supervisor : **Prof. TWAHA ALI BASAMBA Ateenyi**

Signature : ....

Date : 18/12/2013

DEDICATION

To my beloved wife Angele UWIMANA; my sister and brother; my late parents and to all those who have endured sacrifices in one way or another to make me complete this work.

I dedicate this work!

ACKNOWLEDGEMENT

This work has been the fruit of the efforts of many people to whom I feel greatly indebted.

First I would like to pay special thanks to my supervisors Prof TWAHA ALI BASAMBA Ateenyi and Dr KASSIM B. SEKABIRA for their unlimited and continuous support, critical comments and guidance from the beginning to the end of this thesis.

I am very grateful to Soeurs ABENEBIKIRA, Nicole CATRAIS and Réne COMMUNIER, for their kind encouragement and financial support in my orphan's life and in my studies.

Many thanks are extended to all who responded positively to my questionnaire and interviews and allowed to have field survey. Their answers contributed to the result of this research. I will forever be indebted to you.

I cannot forget to acknowledge my classmates for their integrity during the two years of my stay at Kampala International University.

I would also like to express my deep appreciation to the public and private institutions such as Kigali City Officers, Energy Water and Sanitation Authority, Rwanda Bureau of Standards, Rwanda Natural Resources Authority and Rwanda Environmental Management for providing the necessary information for this research study.

In particular way, I would like to thank my beloved wife Angele UWIMANA for loving, encouraging and sharing all the difficulties with me.

Last but not least, I am very grateful to Professor Emmanuel TWARABAMENYE and Dr. Gaspard RWANYIZIRI (Lecturers of National University of Rwanda), without whom this work could have never been started. Their great paternal sense and understanding, allowed me to become what I am today.

Thanks to the Government of Rwanda through Rwanda Education Board for financial support.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ACRONYMS

BADEA	Arab Bank for Economic Development in Africa
EDPRS	Economic Development and Poverty Reduction Strategies
EICV	Enquête Intégrale sur les Conditions de Vie
EWSA	Energy, Water and Sanitation Authority
FBI	Fond du Bienêtre Indigène
GIS	Geographic Information System
GPS	Global Positioning System
MDGs	Millennium Development Goals
MINECOFINE	Ministère de Commerce et de Finance
MININFRA	Ministry of Infrastructure
MINITERE	Ministry of Lands, Environment, Forestry, Water and Mines
NCS	National Census Servsice
NISR	Rwanda National Institute of Statistics
RBS	Rwanda Bureau of Standards
RECO	Rwanda Electricity Corporation
REMA	Rwanda Environmental Management Authority
RWASCO	Rwanda Water and Sanitation Corporation
RWFs / FRWs	Rwandan Francs
SPSS	Statistical Package for Social Scientists
UNEP	United Nations Environmental Program
UNICEF	United Nations Children Emergency Fund
WHO	World Health Organization
WSS	Water Supply and Sanitation Services

ABSTRACT

There is insufficient freshwater in the world for everyone's essential personal and domestic needs (Johns, 1998). However, lack of distribution networks and working systems to extract groundwater or harvest rainwater; exclusion from these services or facilities; inequitable allocation of water resources; and pollution, limit people's access to sufficient clean water. Large numbers of households in cities around the developing world do not have access to safe drinking water.

This study was about urban potable water availability and accessibility in Kigali City, especially in the selected sectors of Gatovu, Nyabugogo, and Kacyiru in Kigali city. A field survey was conducted using questionnaire that were administered to 100 respondents selected purposively. Statistical data analyses were performed using SPSS version 16.0, and maps were produced with Arc GIS software version 9.3 and 10. The water quality was studied in the laboratories and analyzed by Rwanda Bureau of Standards (RBS). Pearson correlation coefficient (PrCC) was done to analyze the associations between the Physico-chemical contaminants in the potable ground water sources such as River water, improved ground well and rain water.

The water quality in the available water sources was however below or within acceptable levels of drinking water in comparison with WHO (2011) standards. Physico-chemical and bacteriological characteristics tested were in the range that is palatable to humans. Furthermore, the existing water network was not evenly distributed over the entire area of Kigali city which showed lack of safe potable water in many areas. Poor availability and accessibility of potable water have negative impacts such as diseases, accidents, insecurity for vulnerable groups like women and children, and economical constraints like high costs of water bills and transport for long distances. Based on current situation, there is need for government to improve rainwater harvesting and management in Kigali city.

Key words: *Potable water, availability, accessibility, governance, physico-chemical, management.*

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Improving access to water supply and sanitation services (WSS) has been an issue on the development agenda for decades now but still these services fail to reach a substantial proportion of the world's population. Every year, this becomes more of a challenge due to factors such as geopolitical changes, rapid population growth and increasing urbanization. In the year 2000 approximately 1.1 billion people lacked access to *improved water supply* and about 2.4 billion people were not served with *improved sanitation* (WHO, 2003). According to a number of international conventions and declarations, priority should be given to water supply, but linked to this and therefore equally important, is the disposal of waste water and human excreta. As a consequence, both water supply and disposal of waste water and human excreta need to be treated jointly (UN-Habitat, 2003).

According to Antony (2000), water covers 3/4 of the earth surface and so it is the most common liquid on the earth. However, inadequate access to drinking water or domestic water constitutes one of the main challenges of human population life on earth, especially in developing countries. According to WHO (2006) some 1.1 billion people worldwide were still using water from unimproved sources in 2002, mostly in Sub-Saharan Africa, where 42% of the population was not served with safe potable water (Fig.1). According to the UN report 2012 on millennium development goals, the projections indicated that by 2015, more than 600 million people worldwide will still be using unimproved water sources.

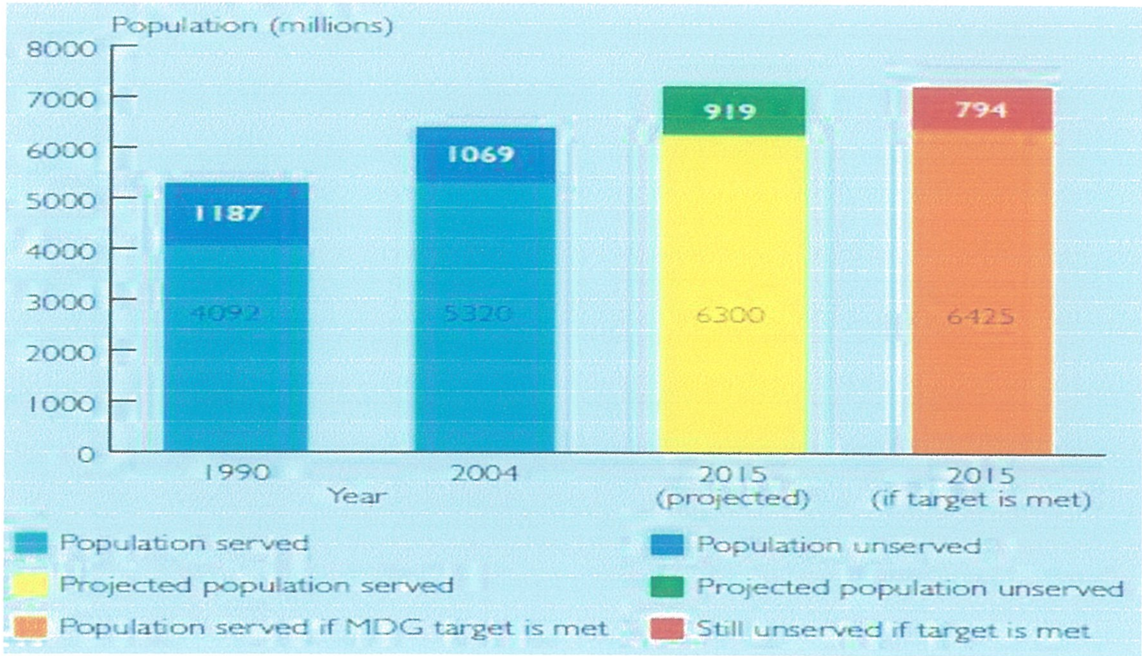


Fig. 1: World population with and without access to improved drinking water sources in the years 1990, 2004 and 2015.

Source: WHO (2006) and UNICEF (2006).

At the beginning of the 21st century, many people faced formidable challenges to meet increasing demand for water. However, there are significant pressures that make it difficult to meet these demands, including inefficient agriculture, expanding urban areas, water pollution and international conflicts. The situation has led many in the international development community to point to a '*global water crisis*'. Projections indicate that in 2015, more than 600 million people worldwide will still be using unimproved water sources (UN, 2012). Data from Energy, Water and Sanitation Authority in Rwanda (EWSA) show that in 2005, water demand in Kigali city was 55, 080 m^3/day, whereas nominal production was 30, 525 m^3/day. Water is accessible from easily and freely available unprotected sources (unprotected springs, open wells and surface water bodies) (MININFRA, 2010).

1.2 Statement of the problem

Rwanda has a water policy aimed to ensure safe, available, accessible, reliable, financially viable and affordable urban potable water supply services for all the people. However, a large number of people in urban areas seem to exceed the planned water infrastructure and supply chain. Many people living in urban areas of Rwanda do not have access to safe drinking water because of lack of affordability to pay water bills due to low incomes, illiteracy and negligence of rainwater harvesting and management technologies. Some families can access water through community water points, where they are charged a user fee for the water depending on the container size or monthly consumption or are uncomfortable with inappropriate tariff regimes related to drinking water. It is very obvious that the consequences of failing to tackle the problems linked to inadequate availability and accessibility to safe potable water are dimmed prospects for the thousands of urban populations locked in a cycle of poverty and diseases. Rain water harvesting of city settlements due to atmospheric pollution needs to be ascertained of its safety too. Aerosols may make it unsafe.

However, many cannot afford clean tap or piped water and have to use water from local streams, pit wells and ponds, which put them at risk of contracting waterborne diseases. Children are more vulnerable than any other age group to the ill effects of unsafe water, poor sanitation and lack of hygiene, with 80% of waterborne diseases. There is need for improvement of Kigali city water infrastructure and quality especially in its peri-urban zones so as to meet urban drinking water needs and both WHO and REMA potable water standards. This can be achieved through proper research and information on the availability, accessibility as well as creating awareness on the water quality standards of the sources to decision makers, city planners and the entire water supply service providers.

1.3 Objectives of the study

1.3.1 Main objective

The main objective of this research was to assess drinking water sources availability, accessibility and quality for the urban communities in Kigali city, Rwanda.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To analyze the spatial availability and accessibility of potable water sources in Kigali City

ii. To assess the quality of the available ground water sources and rain water used by urban communities in Kigali city

iii. To appraise the challenges faced by urban communities due to lack of safe drinking water for urban communities of Kigali city

1.4 Research questions

This study was guided by the following research questions:-

i. Which kind of drinking water sources are used by people in Kigali City?

ii. How is drinking water points distributed in the city?

iii. How long is the distance walked by household to reach drinking water sources and the Waiting time for fetching water from (a) improved source (b) unimproved?

iv. What are the daily water consumption/total house hold use and/or the per capita water?

v. How effective is the implementation of the safe water supply guidelines in ensuring water availability, accessibility and affordability to the people in Kigali city?

vi. To what extent are people harvesting and using rain water in Kigali city?

vii. What is the nature of the Physico-chemical characteristics of the available ground and rain water for Kigali city communities?

viii. What are the challenges faced by urban communities in getting safe potable water?

1.5 Hypothesis

The study used the following hypotheses:

i. Lack of safe potable water is not significantly related to unimproved systems of Kigali water infrastructure.

ii. There are no bacteriological and heavy metal contaminants in potable ground water sources and rain water used in Kigali city.

1.6. Significance of the study

The study highlights on the challenges of availability and accessibility to safe potable water in relation to meeting the demands of the growing urban population of Kigali city.

The study targets to help in orienting investors in urban drinking water related projects and private companies by providing adequate spatial data on the presence and distribution of water sources; and to expose field realities that for where drinking water is more needed.

The information generated helps EWSA and the Government of Rwanda to better understand the problem of potable water in Kigali city and other towns in different regions to cover the gap of lack of safe drinking water and achieve the MDGs objective and a better Rwandan social welfare. The study provides policy makers, local governments and other stakeholders with recommendations which can be used to improve sanitation and safe water provisions to urban populations in Rwanda.

1.7 Scope of the study

1.7.1 Content scope

This study was focused on assessing urban potable water sources availability and accessibility in Kigali city, Rwanda. Spatial distribution of the water sources was established through research surveys made throughout the study area and face to face interviews with different respondents in communities living in Kigali city. The quality of available ground water sources was determined by laboratory tests for Physico-chemical parameters presence. Similarly, rain water samples were also analyzed for bacteriological and heavy metal contaminants presence to ascertain which source is safer for people to use in relation with REMA (2009) and WHO (2011) drinking water quality standards. Kigali is the largest city in Rwanda, located in the central geographical region of Rwanda. The rapidly growing City of Kigali is not only the national capital, but also the country's most important business centre and main port of entry.

1.7.2 Time and geographical location scope

The study took six months conducted between the months of January to June 2013, and was focused on urban drinking water infrastructure, quality of potable water and how urban people access and afford that water.

The study was done in four sectors of three districts in Kigali City, depending on the magnitude of problems faced due to lack of safe potable water as revealed by previous reports, population distribution and settlement relative to water infrastructure, income and how the city expand in the region.

The four selected sectors were: Kanyinya Sector of Nyarugenge District, Kacyiru and Gikomero Sectors of Gasabo District and also Gahanga Sector of Kicukiro District (Fig.2 below).

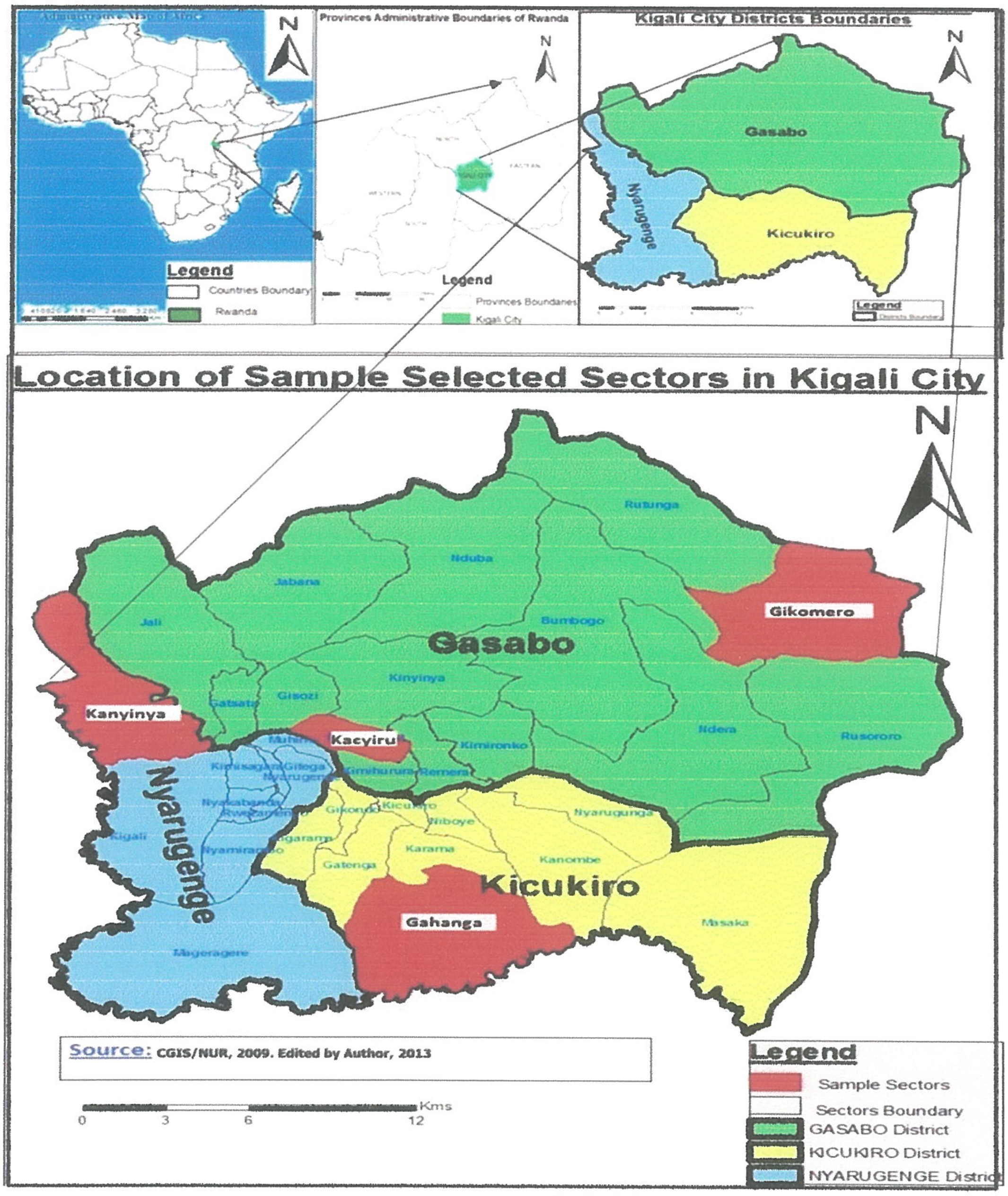


Fig. 2: Location of the study area

1.8 Definition of key Concepts

Improved drinking water source is defined as a type of drinking water facility or water delivery point that by the nature of its design protects the drinking water source from external contamination, particularly of faecal.

Unimproved water sources include unprotected dug well, unprotected springs, tanker truck, surface water (river, dam, lake, pond, stream, and irrigation canal), and bottled water.

Water supply in an area is the water which is collected and passed through pipes to buildings for people to use. It is an arrangement of reservoirs, purification plant and distribution pipes for providing water to a community.

Sanitation is the hygienic means of promoting health through prevention of human contact with the hazards of wastes as well as the treatment and proper disposal of sewage and wastewater (WHO, 2004).

Drinking water is defined as water for ingestion, water for human consumption, is a basic personal and domestic hygiene and cooking.

Water standards are most frequently used references against which compliance levels depending on the category of use of water can be assessed.

Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose.

Rainwater harvesting is the accumulation and deposition of rainwater for reuse before it reaches the aquifer. Uses of harvested rainwater include water for garden, water for livestock, water for irrigation, and indoor heating for houses and drinking water as well.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Potable water sources for urban areas

According to Cap-Net (2009), 97% of global water is seawater and therefore not suitable for human consumption, 87% of the remaining 3% is usable fresh water but is inaccessible to man. This means man only has approximately 1% of global water available for consumption and utilization. Water exists naturally in different forms and locations. It exists in the air, on the surface, below the ground and in the oceans, lakes, rivers, streams, hail storms and clouds.

Potable water is a common pool natural resource for which everyone is responsible. The commodity is highly delicate and vulnerable to pollution and contamination. As such it has to be handled with a high degree of care. The Oxford advanced learner's dictionary (1995) defines water as, 'a liquid without colour, smell or taste that falls as rain, in lakes, rivers, seas, and is used for drinking and washing'. Therefore, if water starts smelling and showing colour it means it is contaminated and no longer qualifies to be water in its pure and natural sense. For Cap-Net (2009) fresh water is not only vital for human survival, health and dignity, but is also fundamental and indispensable for development. Human life, animals, vegetation, the ecosystem, agriculture and many other things, all depend on water.

Gorbachev (quoted in Law, 2005: 7) believes, 'All life is dependent on water to survive'. The paradox, however, is that although water is essential to life and seen as a symbol of purification and replenishment in many religions and cultures, it can also spread disease, breed mosquitoes, cause floods, and so forth. A good fresh water decision can improve the lives of everyone in a community, boost the economy and safeguard the natural environment. A poor fresh water decision can wreak havoc on nature, exacerbate poverty and disease, and create conflict. Rainfall availability, seasonality and reliability is prime in the base structure of safe water as well.

2.2 Availability and accessibility of potable water in urban areas

Africa has the lowest water supply coverage when compared with any region in the world. More than one person among three living in urban areas in Africa are currently lack access to adequate services and facilities. In the year 2000, coverage levels for water supply were 62% (WHO, 2004).

Besides having less urban infrastructure, Africa is urbanizing faster than any other region. Between 1990 and 2025, the total urban population is expected to grow from 300 to 700 million; and it is expected that over 50% of the population in Africa will reside in urban areas. In adopting the Millennium Development Goals, the countries of the world pledged to reduce by half the proportion of people without access to safe drinking water and basic sanitation. The results so far are mixed. With the exception of sub-Saharan Africa, the world is on its way to meeting the drinking water target by 2015 (WHO, 2004).

With an estimated population of about 8,162,175 inhabitants in 2002 and an annual population growth of about 3.1% in general, Rwanda is one of the most densely populated countries in Africa (310 inhabitants per km^2). Rwanda's towns are newly and rapidly urbanized. Since 1990, rural settlers have migrated to development growth points significantly. From 3% in 1970 to 5.6 % in 1991, the urbanization rate has increased to 16.9 % in 2002 (NCS, 2002) and around 19.3 % currently.

Rwanda has committed itself to reaching very ambitious targets in water supply and sanitation, with the vision to attain 100% service coverage by 2020. The government of Rwanda has a target to achieve 100% access to clean and safe water to all citizens by the end of the year 2017. With this target, it is indispensable to assess the real level of water accessibility in Kigali community (EWSA, 2013). The importance of adequate water supply and sanitation services as drivers for social and economic development, poverty reduction and public health is fully acknowledged in Rwanda's flagship policy documents and political goals (MININFRA, 2010). Currently, the Government is trying to increase the supply and water infrastructures to cover most parts of Kigali city such as Jali, Jabana, Bumbogo, Ndera, Gahanga and Masaka.

This policy presents the sector's approach on how to achieve Vision 2020 of Government of Rwanda and 2015 of MDGS as cited that the Millennium Development Goals (MDGs) plan to "Ensure favorable conditions" and reduce by half the percentage of the population without access to potable water by 2015 (MININFRA,2008). Achieving the sector targets implies coordination of all key players, including the districts, the Ministry of Health, the urban water and sewerage utility, Energy and water Sanitation Authority (EWSA), the Rwanda Utilities Regulatory Agency (RURA) and the Ministry of Natural Resources, as well as development partners.

The non-availability of drinking water has two main negative impacts on the community such as:

(i) The time spent in fetching water is too much, particularly for women and

(ii) The diseases caused by use of dirty water with various consequences on health and social conditions of the population.

Considering Kigali city, people walk over 200 m to reach drinking water sources. According to figures 1 and 2, most of the populations (over 50%) in Rwanda walk over 200 m to reach potable water. Also, the majority use protected dug wells (43.5%), standpipes (23.7%) and non-protected dug wells (15.8%). The provinces whose population walks a long distance (800 m-1,200 m) to fetch drinking water are Kibungo, Kigali Ngali and Umutara. The provinces which have lower water accessibility rate are Byumba and Gisenyi. The Provinces which have lower standpipes water accessibility are Butare, Kibuye, Byumba, and Gikongoro because they have access to locally dug wells. Borehole structure in North Easter that tapers in the dry Ankole-Karagwean on soil series with limited water sources. Rwanda as a Rift valley space suffers loss of close to surface water aquifers due to faults.

When water infrastructure and services are lacking, urban areas are among the world's most life-threatening environments (WHO, 1999). A good example is the Harare cholera pandemic of 2008-2009. Van Vuuren (2010:27) observes, 'Urban residents remain much more fortunate than their rural counterparts. About 57 million people living in Africa's cities have no access to improved water sources compared to the estimated 284 million unserved people living in rural areas'. As put forward by Beukman (2002), in southern African urban centres, services are provided either through tankers, public standpipes (common in Angola, Lesotho and South Africa), and yard and private house connections through reticulation networks. Even though the majority of the urban populations are served, interrupted flows, temporary water shortages and generally poor levels of service are common in many towns and cities. Part of the problem is that the infrastructure is either old (Lusaka), destroyed (Maputo) or just poorly maintained (Zimbabwe).

Generally, national governments sell to bulk suppliers who then supply local authorities. Municipalities are responsible for managing water services as far as the end consumer is concerned. In South Africa, the local authority level is further complicated by distinctions between all the water services bodies – including Water Services Authorities (WSAs), Water Services Providers (WSPs), Water Boards and Water Services Committees (DWAF, 2001).

According to International Water Association (IWA, 2004), "access to good, safe and reliable drinking water is one of the most basic needs of human society and as such requires integrated approach, close cooperation and partnership between all stake holders". (IWA. 2004), Research has shown that access to good, reliable and sufficient water supply increases the health status of people. However it is unfortunate that many people in the world today are lacking such quantity and quality of water needed. In some nations they recycle sewage because it is cheaper to treat than the salty water processing expense.

Global Water Partnership (2000) has observed that although most countries give first priority to satisfaction of basic human needs for water, one fifth of the world's population is without access to safe drinking water and the service deficiencies primarily affect the poorest segments of the population in developing countries. It goes on to say that: "water supply and sanitation for both urban and rural areas in these countries represents one of the most serious challenges in the years ahead" (GWP, 2000).

UN-Habitat (2003b), in its introduction of the book- water and sanitation in the world cities, indicated that many cities face serious water shortages and that millions of urban dwellers have inadequate provision of water, sanitation and drainage, which contributes to very large disease burdens and thousands of premature deaths each year. It states that: "less than half the population in most urban areas in Africa, Asia and Latin America have piped to their homes and less than one- third have good quality sanitation" (UN-Habitat 2003b).

Water has always been a very important issue on the United Nations (UN) agenda. When defining the Millennium Development Goals (MDGs), water was also taken into account as one of the aspects for ensuring environmental sustainability. The aim of the UN is to reduce by half the proportion of people without sustainable access to safe drinking water by 2015. We are now in 2006, 9 years away from the targeted time, but it is not clear what has significantly been done in the various regions towards the achievement of the goal.

2.3 Urban water resources degradation and quality in Rwanda

Rwanda is a small landlocked country with an area of 26,338 km^2 (RDG, 2007). It is the most densely populated country in Africa with an estimated 310 inhabitants per km^2. According to the national census, the total population was 8,162,175 in 2002 and annual population growth approximately 3.1% (MINITERE, 2004). Rwanda is endowed with a dense hydrological network comprising of numerous small rivers, streams and wetlands that drain into lakes and other reservoirs .The annual rainfall varies from 700mm in the Eastern part of the country to about 2,000 mm in high altitude of North and West (MINIRENA, 2011). The country water resources are divided into two main drainage basins, the Nile and Congo. The Nile basin occupies 76 percent of the country's surface area and drains 90 percent of its water through Akagera River. The Akagera is the main tributary feeding Lake Victoria, which provides alone an estimate of 10 percent of the Nile's water. Also, Virunga highlands which is a watershed catchment of Virunga ranges and the Kigezi highlands that have characteristics of high altitude-wetland systems difficult to contaminate (UNEP, 2011).

Water quality degradation has been one of increasing issues for fresh water resources in Rwanda. The main source of water pollution in urban areas is lack of adequate sanitation, and inadequate and inappropriate waste management practices. In City of Kigali, for example, 60% of the population depends on shallow pit latrines. Only 24% of the solids wastes generated in City of Kigali is disposed of at the Nyanza land fill (Kigali City, 2007). Kigali Conceptual Master Plan, Kigali.) Hence, untreated domestic and industrial wastewater effluents are the most sources of pollutants that threaten the country's water resources, rendering it unsuitable for direct consumption and increased cost for treatment before utilization (Sano, 2007, Umuhoza, 2010). It has resulted elevated nitrates in the country's watercourses (UNEP, 2011) and heavy metals accumulation in soils, plants and fishes in industrial areas of Nyabugogo swamp (REMA, 2010 cited in Sekomo, 2010).

In addition, industrial related water pollution impacted Nyabarongo river at downstream near City of Kigali with high nutrients concentrations in Nyabugogo river, the affluent of Nyabarongo river(NUR, 2002). At last, others rivers show high turbidity as consequence of landscape and erosion, with high concentration of iron and manganese (LVBC, 2008). Moreover, pollution of rivers and lakes by water hyacinth and other aquatic weeds is a new issue for water resource management in Rwanda which needs to be addressed (MINIRENA, 2011). The consequences of water pollution in Rwanda are high human deaths and illness, especially due to waterborne diseases consecutive to microbial contamination (Dusingizumuremyi, 2007). In addition, high water turbidity conducted to limited operations of hydropower plants and increased cost for sediment removal in water supply (UNEP, 2011). Hence, long term water quality monitoring is required to assess the extent of the problems and identify the sources of pollution with accuracy. This further relates to changing lifestyles and contaminant sources that must be monitored over time to limit them pollute the sources.

2.4 Challenges faced by urban communities in accessing safe potable water

Rapid urbanization in Rwanda, as it is in other developing countries, is a big challenge for town administrators, planners and engineers, as it comes along with high demand for water infrastructure. Cities are struggling to meet the ever increasing demand and there are no signs that adequate water supply have been provided in the near future to the people living in urban areas. Failure in expending and extending this service to reach all people has been due to many factors, including lack of financial resources to invest in new infrastructure, existing infrastructure which doesn't pay back because of inefficient management, inability to plan for services and that existing infrastructure were built to cater for minority people during the colonial period on supply based approach when the cities were smaller than they are today (Nilsson, 2006).

With the growing urban population reported in many developing countries, water utilities need to quickly adopt robust plans and strategic actions. Rwanda possesses abundant water resources. However, the distribution of drinkable water is still inadequate and the rate of access in the country is estimated at 54% (LVRWSI, 2007).

The foregoing shows that generally speaking, the main challenge to water provision is neither water stress nor the scarcity of water. The major problem is the governance of potable water supply and the attitude of the relevant authorities. Water stress and scarcity are symptoms of the overall poor governance of public and natural resources (COHRE, AAAS, SDC and UN-HABITAT, 2008).

Water shortages and increasing pollution are to a large extent socially and politically induced challenges. These challenges are issues that can be addressed by changes in water demand and use and through increased awareness, education and water policy reforms

(UNESCO, 2006). The current global water crisis is thus increasingly about how people, as individuals, and as part of a collective society, govern the access to and control over water resources and their benefits. COHRE, AAAS, SDC and UN-HABITAT (2008: 9) outline the current global levels of lack of access to water and sanitation under four subheadings as follows:

Exclusion of particular groups in planning and political terms, poor people are excluded from decision-making, and their needs are seldom prioritized; resources are used to fund large-scale projects, such as dam construction, rather than lower cost alternatives, such as rainwater harvesting which are more likely to reach the majority of people in rural areas who have no access to water and sanitation services; in some situations, unpopular minorities are excluded from access to water and sanitation for political reasons; deprived urban areas, remote rural areas, semi-arid and arid areas are frequently neglected or intentionally excluded from government programmes for infrastructure development and maintenance; and there is a lack of culturally sensitive and pro-poor policies for the allocation of water resources between the different sectors of water use, and also within these sectors.

Insufficient allocation of resources that exists as insufficient recognition by governments and international organizations that access to safe water and sanitation services has a positive impact on other development objectives such as water and sanitation generally do not receive the priority they deserve in national budgets from Government sectors like Ministry of infrastructures (MININFRA) and in allocations by international donors; and although the principle of cost recovery should not become a barrier to access to safe water by poor people, this consideration is insufficiently addressed when it comes to setting tariff structures for water services.

Changes in management and ownership of water supply and services include shifts in land use and ownership are reducing or limiting access to previously available water sources: agricultural land on the edges of cities or towns is increasingly being used for housing or industrial purposes, often leading to contamination of existing wells or traditional water sources; management of water supply and sewerage services has been delegated to private corporations in some countries, primarily in larger cities, leading to higher tariffs; and decentralization policies in many developing countries such as Nigeria, Ethiopia, Uganda and Rwanda are transferring responsibility for water and sanitation from the national to the regional or local (municipal) level, but the necessary capacity and finances are often not transferred to the newly responsible units, making it difficult for them to manage services adequately.

For Ashton, *et al* (2001), all countries face severe and growing challenges in the management of water resources because of several reasons: the population continues to grow; water supplies continue to dwindle because of the resource depletion and pollution; and demand is rising fast because of rapid industrialization, and so forth. The gloomy picture is well summarized by the rate at which water is being depleted in the world as illustrated in the following observations captured from world water development reports (MCUWR, 2005).

Prominent rivers like the Colorado River in the USA, the Yangtze in China, the Indus in Pakistan, the Ganges in India, and the Nile in Egypt are drying up; siltation, over use and pressure reduction due to over tapped and along stream hydro-electric power generation and their effect; the Aral Sea in Central Asia was the fourth largest lake in 1960 but by 1970 it had shrunk to 10% of its original size; the five great lakes of the USA and Canada; Erie, Huron, Michigan, Ontario and Superior are shrinking at an alarming pace; lake Chad has shrunk by 95% since the 1960s and may disappear entirely; water withdrawals have increased more than twice as fast as population growth; and two million tones per day of human waste are deposited in freshwater courses.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research population

The target population of the study included the household heads and family wives, local leaders, water Companies representatives, the private sector and NGO staff involved in potable water supply or management services within the selected four sectors in Kigali city. Water quality assessment was then done after establishing the available water sources and the rain water samples collected in three different phases (Fig.3).

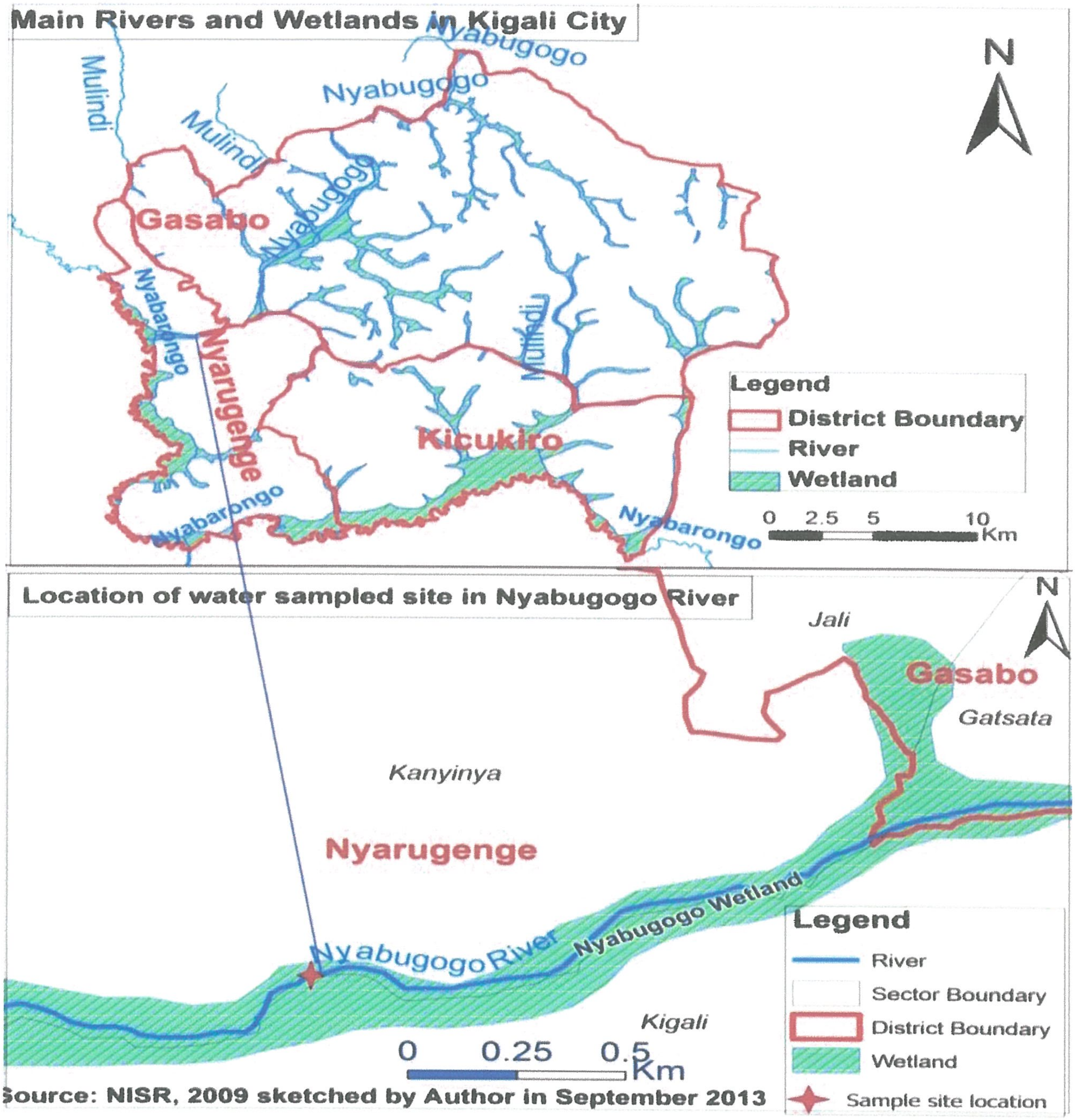


Fig. 3: A map of Kigali city showing unimproved water source-Nyabugogo River

3.2 Research design

This study used a descriptive research design which used both qualitative and quantitative techniques. Survey method was used to traverse through the four sectors of Nyarugenge, Gasabo and Gicukiro Districts which make up the entire Kigali city. Even though different populations had some characteristics that differentiate them from another, other populations had similar characteristics according to Mugenda (1999). The researcher used a rational selection of representative population respondents using "purposive sampling". The choice of the sample was based on the judgment of the researcher to the ability of the respondent in providing the necessary information about urban portable water availability and accessibility in Kigali city.

3.3 Sample Size

The researcher obtained the spatial distribution of availability and accessibility to safe potable water sources by the urban communities in Kigali city through interviewing house hold members of selected families. To get the number of households to be interviewed using questionnaires, Slovene's formula was used to compute the sample size. Slovene's formula states that:

$$n = \frac{n_0}{1 + \frac{n_0}{N}} = \frac{n_0 \times N}{N + n_0}$$

Where n= required sample size; N = Universal or given population; n_o = Constant

Replacing n_o and N by their values. the sample size is: $n = \frac{100}{1+\frac{100}{102746}} = \frac{100 \times 102746}{102746 + 100} = 99.9 \approx \mathbf{100}$

The total number of required sample size is 100.

The number of households surveyed was 100 distributed in Kicukiro, Gasabo and Nyarugenge districts in their selected sectors located in Kigali City (Table 1) and the sampling sites for water quality studies are located in the selected sectors (Table 2).

Table 2: Distribution of household surveyed by district and sector

Districts	Sectors	Male	Female	Total population	Number of households sampled
Kicukiro	Gahanga	13986	13873	27859	**27**
Gasabo	Kacyiru	19844	17054	36898	**36**
	Gikomero	7958	8608	16566	**16**
Nyarugenge	Kanyinya	10448	10975	21423	**21**
Total	4 Sectors	52236	50510	102746	**100**

A field survey was conducted using questionnaire that was handed in to 100 respondents selected purposively. Among them, 98 equivalents to 98 % of all distributed papers were returned.

Table 3: Table 2: Location of sample selected water sources

Location name	Site	GPS Values		Description
		Eastings	Northings	
Gatovu source	G1	511441	9775538	Gatovu water sample 1
	G2			Gatovu water sample 2
	G3			Gatovu water sample 3
Nyabugogo River	N1	502493	9785092	Nyabugogo River sample 1
	N2			Nyabugogo River sample 2
	N3			Nyabugogo River sample 3
Rain water samples collection point in Kacyiru sector	R1	507863	9786993	Rain water sample 1
	R2			Rain water sample 2
	R3			Rain water sample 3

3.4 Tools for data collection

3.4.1 Face to face interviews

Primary data was obtained through face to face interview surveys guided by closed-ended structured questionnaires. In this study, discussions were addressed to two categories of people. One of local communities in group discussions and individual interviews composed of head of households, thus the unit of study for the survey have been a household that have been purposive selected throughout four sectors identified namely: Gahanga, Kacyiru, Gikomero and Kanyinya. The other group is made of key players involved in potable water availability and accessibility in Kigali City at different levels such as local administration; water Companies representatives, private sector and NGO such as World Vision, Water For People and PEWISCO Limited whose priority is water services.

3.4.2 Questionnaires

Questionnaire survey was relied on to the busy persons who did not have much time for oral interviews and had accurate and reliable information about the topic mostly authorities. An official questionnaire was carefully designed and used.

3.4.3 Observation and field reconnaissance

Observation were used to check the quality of water facilities, daily challenges met in search for water and whenever possible picture were taken to serve as on ground evidence. Mobile Geographic Information System techniques were applied for spatial data requisition (coordinates using GPS or IPAQ with Arc-Pad software) such as collecting information about the location of water infrastructure such as water standpipe and boreholes and for tracking where the pipelines pass in order to show pipelines in good conditions and others in bad conditions.

3.5 Laboratory testing

Physico-chemical characteristics tested included the water pH, conductivity, total suspended solids, total dissolved solids, turbidity, and metal elements such as manganese, Iron, potassium, sodium and calcium. The nutrients of non-metals tested included chlorides (halide) and sulfates. The tests also examined potable water sources for bacteriological concentrations by testing for total coliforms. Physical qualities of water tests were done by in-situ procedures using the multi-meter device WTW Oxi 340i model while the chemical (both metals and non-metals) in the potable water were analyzed in the laboratory using colorimetric method with HACH DR/890 model.

A bacteriological concentration of feacal coliforms was done by filtering a sample of water on an ester membrane of cellulose with a porosity of 0.45µm. The faecal coliforms were identified by counting colonies on Petri dishes incubated at 44 ^{0}C for 24 hours whereas total coliforms were identified by counting the colonies on the Petri boxes incubated at 37 ^{0}C for 24 hours.

3.6 Statistical Analyses

Descriptive statistics using frequency tables, percentages, Mean or average, range, standard deviations and graphs for spatial distribution of water sources and in analyzing different water samples (ground water sources and rain water) were done in which computer software such as Microsoft office word, Excel (Version 2003/2007) and SPSS version 16.0 were used. Spatial distribution, availability and accessibility of improved and unimproved water sources in Kigali city was analyzed by descriptive techniques and a comparative analysis between the ground water and rain water accessibility and safeness was established by comparing their means.

Correlation analysis by Pearson linear correlation coefficient (PrCC) was done to analyze the associations between the Physico-chemical characteristics and Physio-bacteriological contaminants in both the potable water ground sources and rain water.

CHAPTER FOUR

4.0 SPATIAL AVAILABILITY AND ACCESSIBILITY OF SAFE POTABLE WATER SOURCES FOR KIGALI CITY COMMUNITIES

4.1 Abstract

Water is present in many areas and can be found on both the surface of the soil and under the surface while other water can be harvested by making use of rain fall. Water is vital for the life and survival of humans, animals and all forms of vegetation on the Earth (UNESCO, 2003; Cap-net, 2009) and Gorbachev (quoted in Law, 2005: 7) believes, 'All life is dependent on water to survive'. The objective was to analyze the spatial availability and accessibility of potable water sources in Kigali city and compare their quality with rain water for safeness to human use. Semi-structured questionnaires and interview schedules were the tools used in data collection. One way ANOVA and Kruskal-Wallis test were used to analyze the results and come up with discussion and conclusions on the safe available and accessible potable water sources in Kigali city.

The portable water variability is a challenge with Kigali urban growth; the infrastructures are constructed but do not match with the urban population growth. On peoples' view on water availability, only 18.4% confirmed that water was increasing and 57.1% said potable water was reducing while 24.5% others responded that there was no change in potable water availability. In the interview with an old women native of Gahanga Sector in Kicukiro District, 62 years old, said that in the past, water was never a problem because the number of inhabitants was sufficient to water quantity of the region. The population explosion and lack of projected resource base sources, conservation and sustainable utilization of water sources today is the biggest problem to most domestic water needs.

It can be concluded that a large population of people (78.6%) living in most peri-urban areas of Kigali city are not having access to safe potable water. These have no connections with safe piped water supply, but rather use other available sources such as communal protected or unprotected springs, rivers and dug wells. Close to 30.61% of the people have

to walk long distances of between 100 m to 1 km to reach their nearest water sources. This eventually makes all form of water source over-exploited.

4.2 Introduction

Rwanda is faced with increased population and low funding to potable water infrastructure, especially in Kigali. Historically, Kigali City started in 1907 as a small colonial outpost with little link to the outside world but it is now over 100 years old. Today, Kigali has come of age-as the capital of Rwanda and made phenomenal strides. It is a city that has not just survived, but has prevailed and has grown into a modern metropolis, a heart of the emerging Rwandan economy and a pride of every Rwandan. The number of people settled in Kigali city exceeds the planned water infrastructure; consequently there is need for its improvement especially in its sub-urban so as to meet urban drinking water needs. The existing water network is not spatially distributed in the same way over the entire area of Kigali city. This implies relative lack of the potable in many areas of the city especially the new urbanized zones those which are located a bit far from the city centre.

Most people living in Kigali city make long distances of between 100 m to 1 km in search of safe drinking water and even more than 2 km when there is a crisis of water from EWSA for searching water from source (Fig. 4). The available water from wetlands, unprotected springs and untreated water supply are major sources threatens people's lives. Few Rwandans have access to piped water (about 21.4% of Kigali population). The recent MINECOFINE (2007) report on sanitation and epidemiology suggested that over 80% of diseases that afflict Rwandans were waterborne and therefore access to safe potable water is a precondition for improving environmental and personal health. Domestic behavioral changes are key factor in controlling episodes of waterborne diseases.

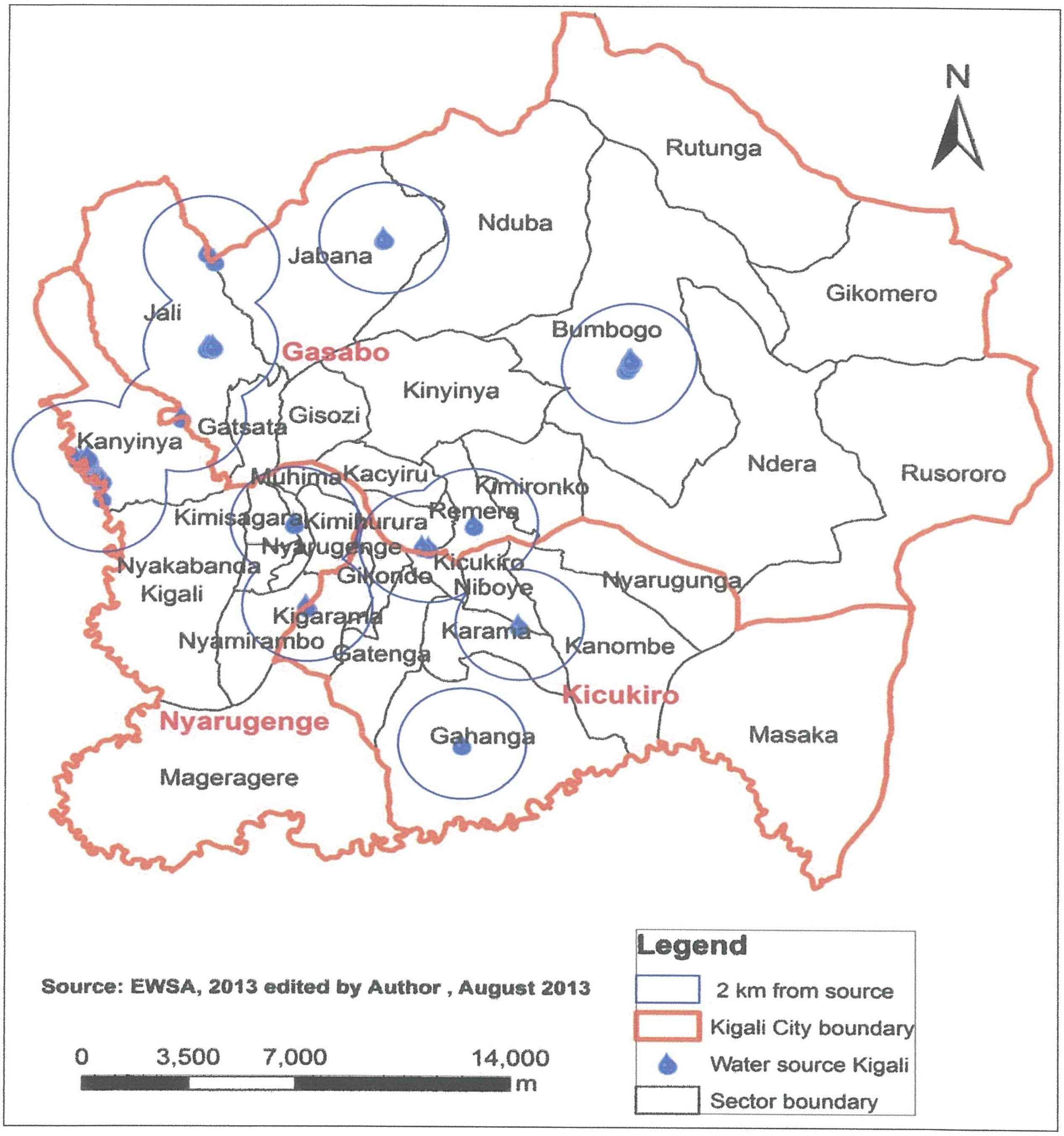


Fig. 4: Existing of groundwater sources and accessed distance of 2km buffer

Some families in Kigali city can access water through community water points, where they are charged a user fee for the water and/or according to either container size or their monthly consumption. However, many cannot afford clean tap water but instead collect water from local streams and ponds, wetlands and rivers while a few can manage to make use of rain water. Such situations put them at risk of contracting waterborne diseases and other unsanitary complexes. Children are more vulnerable than any other age group to the ill effects of unsafe water, poor sanitation and lack of hygiene while women are the most stressed group of persons in society as they cannot have enough water to satisfy their domestic demands.

4.3 Materials and methods

The researcher used a rational selection of representative population respondents using "purposive sampling" during a survey through the selected three districts of Nyarugenge, Gasabo and Gicukiro. The choice of the sample was based on the judgment of the researcher to the ability of the respondents in providing the necessary information. The face to face interviews together with structured questionnaires were used to collected data from 98 respondents. The composition of respondents was 53.1% females and 46.9% males whose age groups were between 15-35 years, 36-45 years and above 45 years.

4.4 Results and discussion

4.4.1 Demographic characteristics of respondents

Table 4: Demographic characteristics of respondents, n = 98

Name of Sector	House hold	House holds%	Sex %		Education level (%)				Type of employment (%)				
			F	M	Non	Pri	Sec	univ	State	Private	NGOS	Relig	None
Gahanga	27	27.6	13.3	14.3	**5.1**	18.4	2	2	1	15.3	0	5.1	6.1
Kacyiru	35	35.7	20.4	15.3	1	9.2	12.2	13.3	13.3	11.2	4.1	3.1	4.1
Gikomeko	15	15.3	6.1	9.2	3.1	8.2	3.1	1	1	6.1	0	2	6.1
Kanyinya	21	21.4	13.3	8.2	4.1	9.2	7.1	1	1	9.2	5.1	1	5.1
Total	98	100.0	53.1	46.9	13.3	44.9	24.5	17.3	21.4	41.8	16.3	16.3	9.2

Table 5: Classification of employment status in relation to education level

		Education level in %				Total in %
		None	Primary	Secondary	University	
Employment status in %	State Employee	0	2	9.2	5.1	16.3
	Private Employee	7.1	24.5	4.1	6.1	41.8
	NGOs Employee	0	0	5.1	4.1	9.2
	Religious Employee	0	8.2	1	2	11.2
	Jobless/Other	6.1	10.2	5.1	0	21.4
	Total in %	13.3	44.9	24.5	17.3	100

The researcher used a total of 98 respondents with 52 females (53.1%) (Table 3) while males were 46 (46.9 %); the majority of respondents 44.9% had only primary school education and a large number of inhabitants in the four sectors selected 41.8% were employed as private employees. University graduates were all employed in different activities and this indicated that at least these households with graduates working had their incomes stable and could afford paying or meeting the requirements for supply of safe potable water in their families. Households with no educated persons or those with members at primary level of education were found to have more jobless persons (table 4). This implied that extraneous variable like the income of an individual or a family in influencing the person's ability to access safe or piped water by EWSA could greatly be felt by such groups, making them vulnerable to waterborne infections.

Other factors responsible for peoples' inadequate accessibility and inability to have safe potable water in their homes were found to be a family size.

Table 6: Family size by sector, n =98

	Number of Family size by selected Sector				
Sector	Single	2 to 3 Persons	4 to 6 persons	> 6 persons	Total
Gahanga	0	2	12	13	27
Kacyiru	6	5	14	10	35
Gokomero	0	4	6	5	15
Kanyinya	0	1	11	9	21
Total	6	12	43	37	98

The statistics in Table 5 show that 6 families or households sampled in Kigali city lived with a single person only, but at least two or more members were found to occupy single housing units. Worse to note was that a large number of households surveyed in every sector contained more than six in mates and majority hosted members of between 4 to 6 members. These are bad news to indicate how fast the Kigali city population is currently changing and growing from the previous low population to a more densely populated city where demand and usage of water has increased greatly, overwhelming the existing water infrastructures which formerly were planned for a few populations.

4.4.1.1 Monthly income

The level of monthly incomes of city dwellers in Kigali is directly linked to the level of education and the employment status, but also directly affects the way people met their family bills such as safe water and electricity among others. This situation is explained by the fact that the more educated, the more people are able to diversify activity and engage business in different fields while those unskilled people may only hardly engage in single and small scale projects. None of the people who never attended any schools has income of above 150.000Frws (220 US$) per month. Only 1% of such class of people has income of between 50.000Frws (75 US$) and 150.000Frws (220 US$) . 64.7% of people attended the university level have income between 50.000Frws (75 US$) and 150.000Frws (220 US$) and only 5.9% of them has below 25.000Frws as monthly income mostly because of nearly finished their studies and not yet get manage the work (Fig.5).

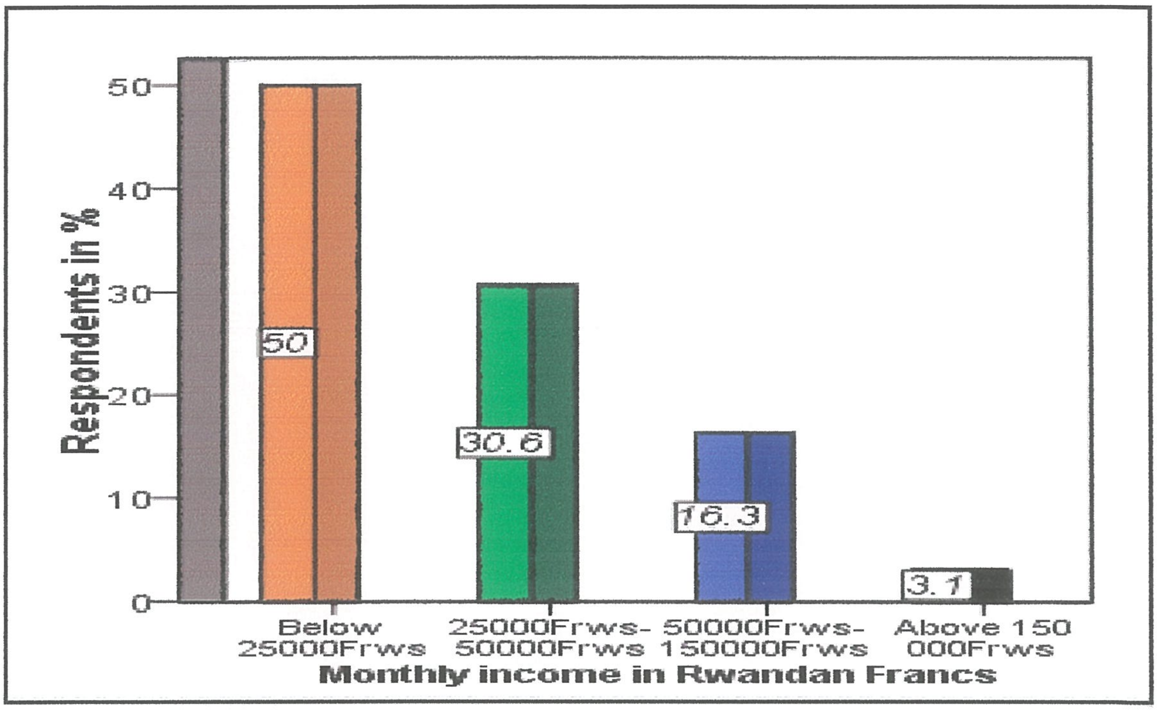


Fig. 5: Monthly incomes of individuals in the sample size, n =98

Thus, monthly incomes generally increase in a chronological order from illiterate, primary, secondary, and finally university proportionally.

4.4.3 Existing water sources and mode of potable water supply

The availability of palatable water in Kigali is varying from different sources and comes from different backgrounds such as underground sources, River water, rain water and recycled water distributed by EWSA to the population.

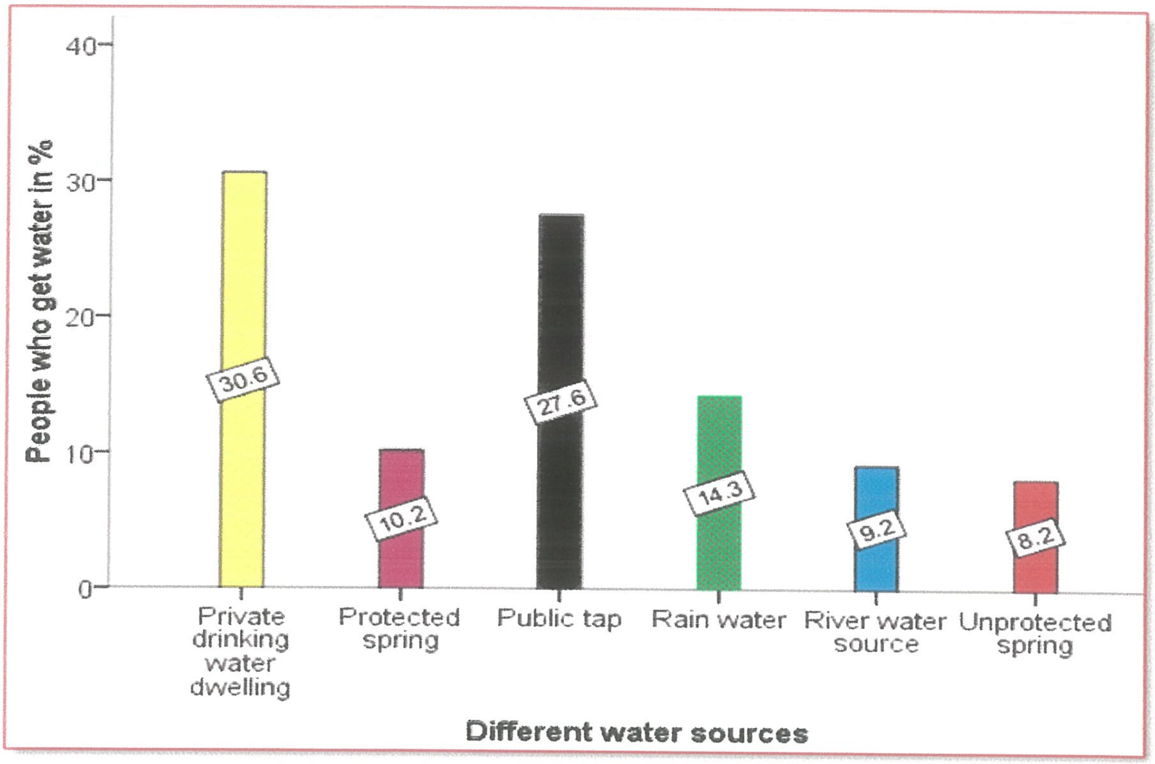


Fig. 6: Different water sources available in Kigali city, n =98

The results showed that majority of people in the study area are using water from private tap water (30.6%) or buy water from the neighbours or have their self standpipes (27.6%) (Fig.6) while others use public taps provided by EWSA which is the only government institution in charge of water supply in Rwanda. The rain water is only used by a few populations of city dwellers (14.3%), but they do not use this source during the whole year because the raining period is limited by the seasons and the way of rain water management is not practiced by all people. Some 9.2% fetch water from rivers, 10.2 % in protected spring and 8.2% use water from unprotected boreholes including the wetlands and tangs. During the study, the people testified that they get water in different ways and majority of them buy water from neighbourhoods (33.7%), 20% of them buy water from public standpipes of EWSA, 17.3% fetch water from boreholes, 16.3% fetch water from wetlands, rivers and ponds while 1% get water from other unspecified sources (Gorbachev, quoted in Law, 2005: 7).

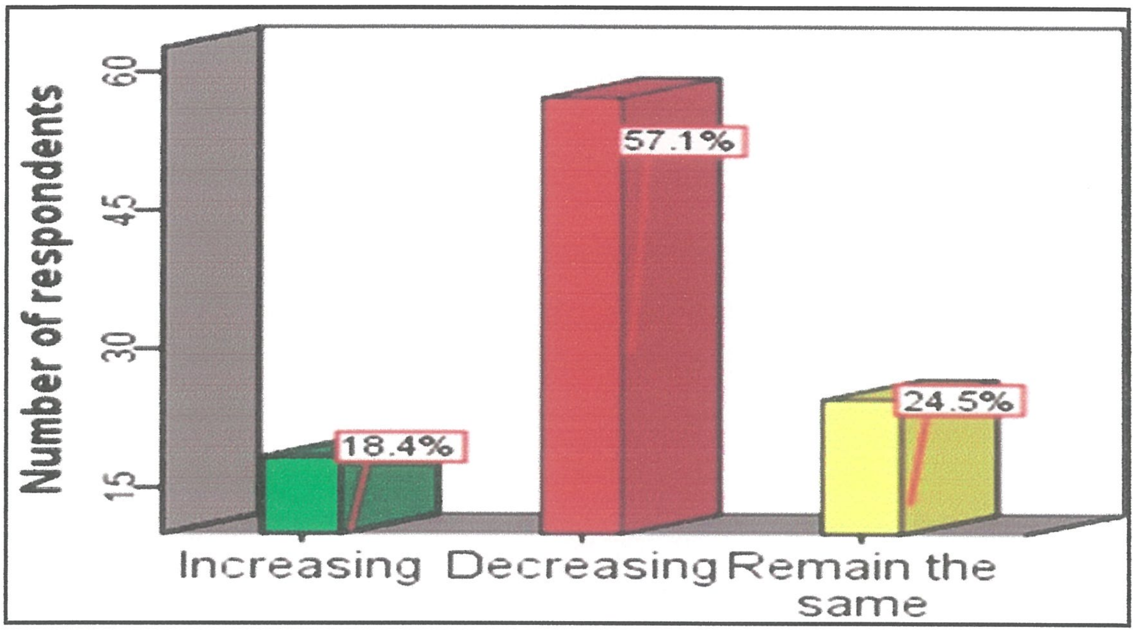


Fig. 7: People's view on potable water variability in Kigali city, n =98

The portable water variability is a challenge with urban growth; the infrastructures are constructed but not much with the urban population growth. The people's view on water variability only 18.4% confirms that water is increase and 57.1% see that water is reduced as the time goes on others 24.5% respond that there is no change (Fig.7). In the interview with one old woman 62 years, a native of Gahanga Sector in Kicukiro District said that in the past water was never a problem because the number of inhabitants was small to water plenty of uncontaminated water sources in the region. This indicate how fast the Kigali city population is currently changing and growing from the previous low population to a more densely populated city where demand and usage of water has increased greatly, overwhelming the existing water infrastructures which formerly were planned for a few populations.

4.4.2 Potable Water Availability

Portable water in Kigali is supplied by EWSA. Kigali City is currently supplied with water from Kimisagara, Nzove, Karenge and some source in town. The current production is lying by 68,000 m^3/day. This is gradually increasing to 93,000 m^3/day with optimization of the water treatment process of Nzove water treatment plant (EWSA, 2013).

Table 7: Older and new water treatment plants constructed in Rwanda

Source	Supplied area	Finalized by	Production in M^3 /day	Funded by
Rehabilitation of Cyondo spring to supply water toNyagatate district	Nyagatare district	End 2010	2000	MININFRA
Increasing water supply to Huye town by reinforcement and renovating Kadahokwa water treatment plant	Huye town	December 2010	4000	BADEA
Support of Muhanga water production to face dry season crisis by using available dams	Muhanga	2011	2000	MININFRA
Water supply project for Rusizi from Ruhondo spring. Increasing of additional 800 m3 capacity	Rusizi	End 2010	1000	RWASCO became EWSA
Optimization of water treatment process of Nzove water treatment plant	Kigali	2011	25000	RWASCO
Construction of a Dyke in Bysha	Nyanza	December 2010	3000	RWASCO
Additional sources to supply Karongi town	Karongi	October 2010	150	RWASCO
Technical and socio-economic feasibility studies to supply water to 7 secondary towns	Muhanga, Ngoma, Rusizi, Gicumbi, Rubavu, Karongi and Nyanza	Ongoing	Ongoing	BADEA

Source: EWSA, (2013)

The survey showed that in the study zone, the 21.4% of people who were found to have tape water connection at their home and the 78.6% have no tap water connection in their home. This percentage has no significant difference to the data obtained from EWSA statistics department, which indicated that 47% of their customers do not get water to fulfill their requirements and this means more people are not connected to EWSA water supplies particularly those living in poor neighborhoods.

The mentioned reasons for lack of connections to piped water supplied by EWSA to Kigali city population were majorly four: - inability to afford high water bill from EWSA (29.9%); difficulty to get subscription to sustain the drinking water infrastructure like public standpipes and borehole, Water connection of 5,000 RWF, Public drinking fountain of 44 US $ or 30.000Rrw (62.3%), other reason was that most people are tenants and not real owners of houses they occupy so it is not wise to connect them to such public water systems unless the owners did installation of home (3%), and only 4.8% of the population surveyed were satisfied with the water they get from EWSA water supplies.

4.4.3 Potable water accessibility, distances and time for fetching water

According to MININFRA, (2010) daily water consumption per capita should be at least 20 liters. Access to drinking water is also a basic amenity, ranked among the highest priority public services by Rwanda's population. Despite all the efforts, the rate of water supply was 54% in 2010 and the daily per capita consumption is of the order of 6 to 8 liters per day in rural areas, far lower than the envisaged standard consumption of 20 liters. While sufficient clean water is essential to everyone's wellbeing great disparity in drinking water accessibility is remarkable among Kigali population.

Statistics from the infrastructure ministry showed that less than 50% of Rwandans use piped water, with around only 5% of them having water within their compounds. This means that on average, women and children can spend between 10 to more than 1 hour daily fetching water in long distances of between 100m to 1km. The reasonable access to water refers to distance walked by households and time spent for reaching drinking water.

According international indicators, the convenient distance is not exceeded to 200 m while the time is 15 minutes as suggested by WHO, (2011).

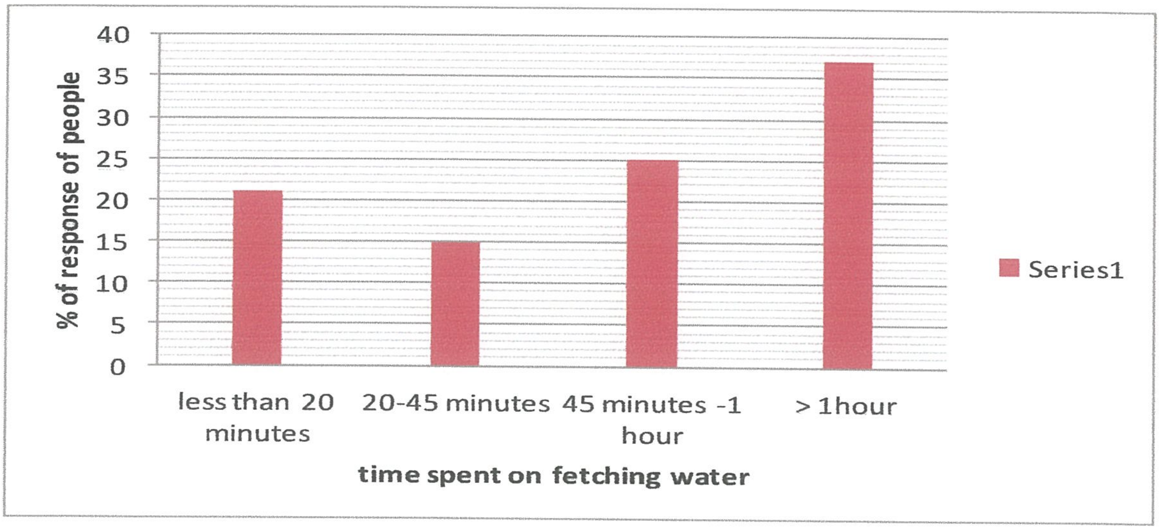


Fig. 8: Time spent on fetching water by people in Kigali city, n = 98

Many households (36.7%) spend more than 1 hour to fetch water at their nearest water sources, only 22.4% of the people interviewed fetch water in below 20 minutes from the nearest water source. Comparing the source of drinking water accessibility to time taken by a person in fetching water, those people connected to piped water by EWSA spend far less time than those who have no water connections (Fig.8).

Plate 1: Photo showing the long time waiting at water collection point in Gahanga sector, Kigali

From the results, only 18.4% of the respondents said that they wait about 5 minutes whereas 25% have to wait from 5 to 30 minutes at public water tap. This waiting time depended on water pressure and number of people who were in waiting. There are various consequences from this waiting. Time is lost while it should be spent for other income generating activities like agriculture, commercial, handcraft, etc. For children who have to go to school after collecting water tend to be late (plate 1).

Many households were found to walk long distances to their water collection sources. The households walking distances below 100m are 22.45% of the surveyed population, where 63.7% of them are those who have water connections in their home. The 15.31% are walking distance between 100m and 500m to reach the water source and most of the surveyed households walked between 500m and 1 km (30.61%) and 31.63% of them walk more than 1km (Fig.9).

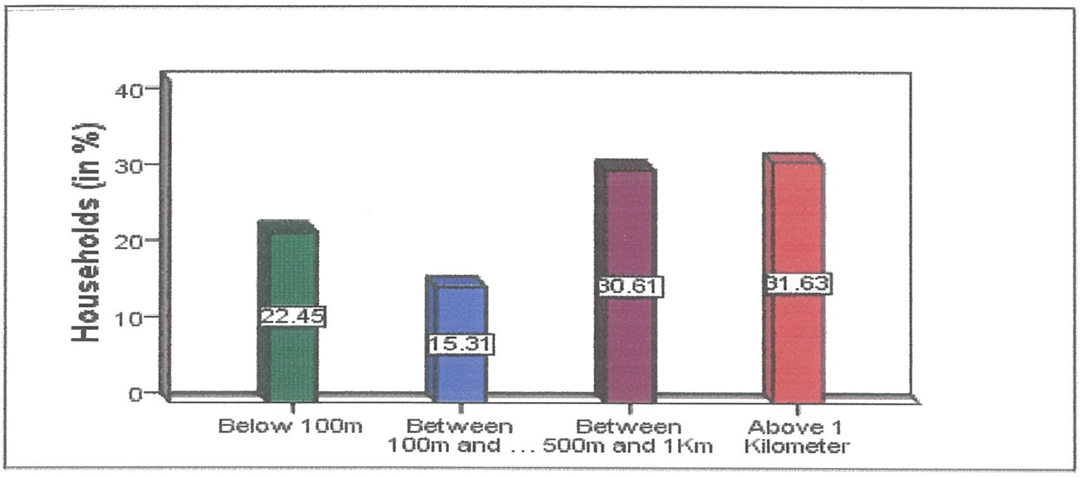


Fig. 9: Approximate distances walked by people in Kigali city to fetch water, n=98

The recommended WHO standard distances to be walked by a person fetching water is <200m. The results mean that there is a problem of water scarcity in many places within Kigali city as evidenced from the four sectors surveyed. The best alternative solution to overcome this challenge would be making use of rain water of which the harvesting equipments and technologies involved have just been adopted by city communities on a very low scale. These findings are threatening according to International Water Association (IWA, 2004), which had suggested that "access to good, safe and reliable drinking water is one of the most basic needs of human society and as such requires integrated approach, close cooperation and partnership between all stake holders".

4.4.4 Potable water affordability in Kigali city

The water tariffs in Kigali ranges from 20 RWFs to 200 RWFs per Jerrycan of 20 liters and varies according to whether the consumer uses a private connection, public tap or gets water from neighboring private water connection, the distance used with additional cost of transport and depend also to the season of the year where the cost increase with dry season. For those who are connected, the principle of paying water bill is in accordance with the volume consumed and a monthly payment made of the number of consumed cubic meters multiply by 600 RWFs. While at public taps water is paid just before collecting it at the price from 20 RWFs to 200RWFs per jerrycan. Local public water point managers are required to respect water tariff and timetable scheduled by EWSA. Engineering services are needed to maintain and repair the broken down water facilities. In the interview with ones of those sellers, they explained that private water connection is costly so that they have to sell at such higher price.

According to the industrial water, they are different private industries, enterprises and companies in charge of water purchasing such as Inyange industries, Nile Natural Mineral Water, E^{st} URWIBUTSO which produce AKANDI Natural Mineral water and many others (Fig.10).

The average cost of 1liter is 500RWFs, this cost may be explained by the water treatment, chemical cost used, taxes, and the interest of these private industries.

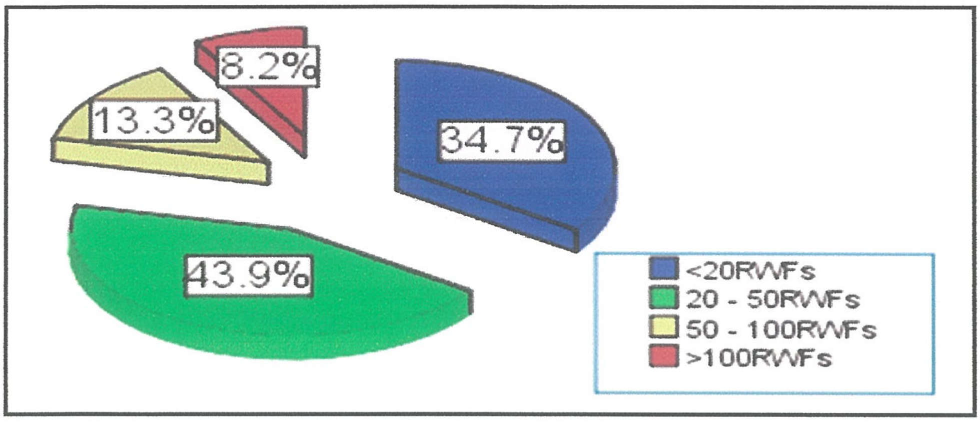


Fig. 10: Variations in water prices per Jerrycan by different users in different places

The majority of the respondents, 43.9% said that the cost of a jerrycan is varied between 20RWFs and 50 RWFs and the 34.7% of them buy water on the amount not exceed 20RWFs while 13.3% buy one jerrycan on 50RWFs up to 100RWFs. Only 8.2% get water at more than 100RWFs per one jerrycan because of mostly the distance transportation cost and the low quantity of water pipe in sub-region.

For the water purchasing from EWSA, as responded by the one officer of the department in charge of customers in EWSA, it is used to conduct several visits to various public water points to check whether managers fulfilled the contractual obligations relevant to the management of water points and to harmonize the cost. During these visits, there were various discussions and meetings either with the managers or with water users in the presence of grassroots authorities in order to identify the problems related to the management of water points, among which the respect of water tariff, cleanliness of public taps and opening timetable; and means to be implemented so as to increase water sales and fight against acts of vandalism perpetrated on the distribution network infrastructural facilities. When the water quantity is not enough, the EWSA publish the timetable of distribution by region and caution communities on wise use in space and time.

The right to drink water is not the right to buy bottles of mineral water but the right to consume drinking water even when users do not have the means to pay for it. In a large number of countries, national law states that drinking water should be available to all even the most dispossessed people, and that the price of water must be equitable, fair, acceptable accessible, affordable or reasonable. However, the content of this right is still unclear even if affordability of water for human consumption remains an official target or a legal requirement in many countries especially in Rwanda where it is clearly specified in EDPRS II and Vision 2020 projects (MINECOFINE, 2000).

4.4.5 *Relationship between income and connectivity to piped water by EWSA*

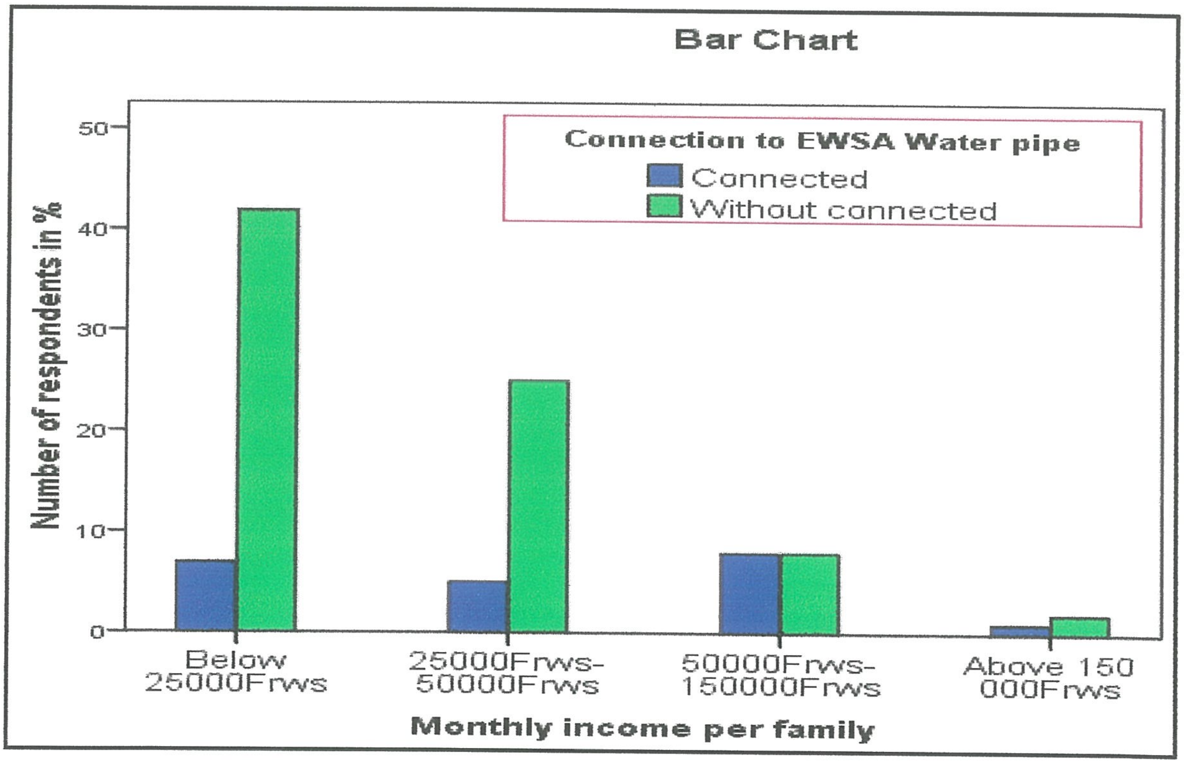


Fig. 11: Extent of supply of piped water by EWSA to Kigali urban communities

In the study area, only 14.3% of people with income of under 25000 RWFs per month have water connection in their home while 85.7% of them are without connected. For those who have income between 25000-50000 RWFs, 83.3% of them are being without water connection in their home. The number of water connection holders to the people with the income between 50000 RWFs and 150000 RWFs is remaining equal while for the people who have income above 150000 RWFs the half of them are with water connection in their home (Fig.11).

The results on supply of piped water to urban communities of Kigali city has not yet complied with the goals suggested by (MININFRA, 2010) "to improve service levels by encouraging household connections and developing pro-poor services is the target of the government. In order to increase the revenue base, raise the standard of living and promote hygiene (by raising water use to international standards) it is desirable to increase the percentage of individual household connections: Less than 20% of the inhabitants of urban areas are currently served by individual connections. The water supply and sanitation sector shall therefore encourage and support efforts of the Utility (or other service providers) to increase the number of household connections, and shall consider targeted subsidy schemes such as social connection programmes".

4.4.5 *People initiatives to contribute in water infrastructure maintenance*

The research showed that majority (55.1%) of the people do the community working called nationally "umuganda in the local Kinyarwanda language" by local government order not by their own voluntary aspect and only 44.1% said they do this by their own will.

This indicated that a large number of people are not aware of the importance to participate or contribute to water infrastructures protection activities. This is based on the low level of their awareness on water protection role and most of them think that it is not their business. They respond that EWSA is there for all activities regarding to water infrastructures. The 25.5% of respondents see that is easy to increase their contribution while 24.4% of them said that it is not easy to find the contribution they pay. The remaining people (54.1) are not contributing at any level of water infrastructures protection and maintenance. In Rwanda, each last Saturday of every month, there is obligation of community working activities; it is when the activities related to water infrastructures protection and maintenance done locally.

4.5 Evaluation of Rainwater harvesting and management

Rainwater harvesting has provided a water source for communities around the world dating back to approximately 1500 Before Christ (Hunt, 2006). This ancient technology continues to serve populations today, mainly in poor, urban, rural or dry regions of the world and island communities. In Kigali city, the rain water is highly used by different categories of people in different uses such as drinking water, domestic use and industrial use, and in car washing services. The 65.3% use rain water and only 34.7% of respondents do not need to use rain water from different reasons. The 8.2% of the respondents said that they do not need to use this kind of water because they have enough water or they are near water source. Others 25.5% of respondents not have access to rain water because of limited financial mean to harvest rain water.

4.5.1 System of rain water collection

The most basic systems require only a rain catchment in area (Closed way system on the roof), a conveyance system (e.g., gutters, downspouts, plumbing) and a holding tank. These systems grow in complexity in order to address the quality of water captured (i.e., treatment) and the ease of its use (e.g. pumping for indoor toilet use) (La Branche et al, 2007).

Table 8: Different methods used to collect/harvest rain water

System to collect rainfall water	Respondents in %
Rainwater reservoir and tanks	19.4
Water gutter through roof only	18.4
Closed way system on the roof	20.4
Other systems	9.2
Do not use rain water	32.7
Total	100

The study showed that the households who use rain water (20.4%) claim that they use rain water as additional drinking water and collect this water through closed way systems on the roof (Table 7). Only 19.4% of households use the rain water reservoir and tanks of the total population sampled. These were categories of families whose income were moderately good but not first class families. There are 9.2% who responded that they use other methods than those cited such as water collection with drainage water to their ponds or holes. Those who collect water through roof only (18.4%), is because they are poor so that they cannot afford the expensive rain water collection materials or ignorance to none prioritize water in their home budgets.

The methods used to harvest rain water depend on the economic income of the household and. There are different methods of water collection depending on the income, awareness on the role of rain water and quality of the nearest water source. The Plate 2 shows the water collection method in one of water sources. Just a drop is too much loss! Education of masses on wise use and conservation.

Plate 2: Photo of Gatovu ground water source collection in Gahanga sector, Kicukiro District, Kigali city

4.5.2. What the people use rain water for?

A proper analysis of the rain water usage this study was an important component to assess urban potable water availability and accessibility. The households in the sectors surveyed in Kigali City use the rain water in different domestic activities, toilet flushing, irrigation of garden and many other roles, but the extent of harvesting and using this alternative water source is limited to a few households who can afford the materials.

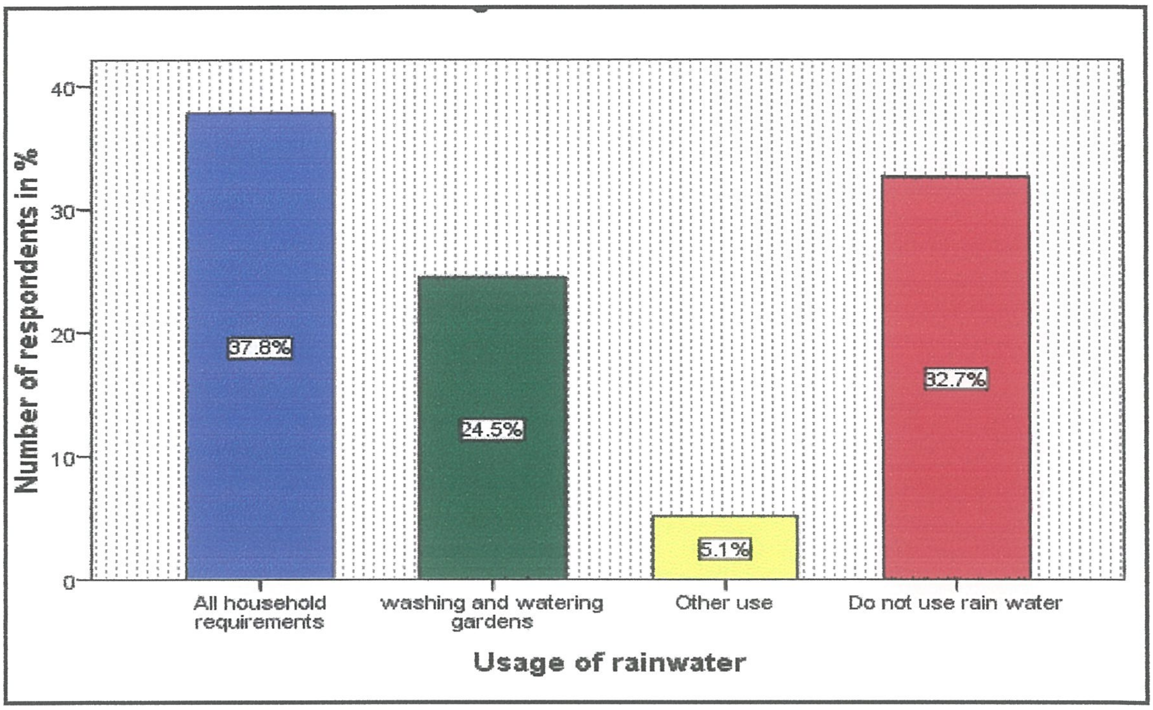


Fig. 12: Rain water usage by Kigali communities in different purposes

The rain water in Kigali is mainly used in households' requirements by 37.8% of all surveyed households. The 24.5% of them are using rain water only in washing and watering their gardens (Fig.12). Minor amount number of households (5.1%) uses this water in other activities such as toilet flushing, swimming pool, small urban agriculture, and construction.

4.6 Conclusion

According to the judgment of the Kigali City Council officials, certain assertions like high water prices from vendors; too much time is wasted in search of water; children usually are either late or absent from school and risking their lives when crossing the roads to fetch water are all major problems in the water problem deliberation to Kigali city populations. The inaccessible and unsafe potable water to many poor people in the city coupled with long queues in fetching water; increase of prices of food items and risk in drinking untreated water were impacts of the water scarcity problem. Improving and providing the inhabitants with materials for rain water harvesting and extending the piped water to most slummy places of Kigali city can minimize the impacts of water shortages. Handouts to society are not good practice. People should be taught methods/mechanisms and ways and be supported to evolve a system of clean and safe water management, otherwise, their lack of involvement and participation may result into "Easy come easy go" syndrome in which the people will not care about the installed water supply systems. They can continue to think that maintenance of water sources and other problems arising are to always be solved by the Government.

CHAPTER FIVE

5.0 A COMPARATIVE ASSESSMENT OF POTABLE GROUND WATER AND RAIN WATER QUALITY IN KIGALI CITY

5.1 Abstract

Urban water infrastructure typically includes water collection and storage facilities at source sites, water transport via aqueducts (tunnels and/or pipelines) from source sites to water treatment facilities; water treatment, storage and distribution systems; collection sewage systems and treatment; and urban drainage works. The quality of water available for human consumption is affected by several of such activities and processes. The objective was to assess and compare the quality of potable ground water sources and rain water used by urban population in Kigali city. Water quality was determined at six selected water points representing both improved and unimproved sources. Three from protected/improved water sources in Gatovu area (G1, G2 and G3), three from Nyabugogo River (unimproved potable water N1, N2, and N3) and compared with the quality of three rain water samples got in three months of between January to June 2013.

The findings indicated that the water in both improved and unimproved ground water sources contained heavy metals and microelements at levels above the normal palatable standards of WHO (2011) and REMA (2009). People were generally not satisfied with the quality of potable water they use as well as the services provided by EWSA because the water quality was not good and walking long distances to water sources was noted as a risky and tiresome activity to the vulnerable women and children. The water cost was considered high especially for the poor who could not afford the cost and therefore used alternative unprotected services.

In a nut shell, there were several reasons to believe that some people had not adjusted to preference for treated water and are still using the traditional sources of lower water quality.

5.2 Introduction

Access to water is a prerequisite for health and livelihood, which is why the MDG target is formulated in terms of sustainable access to affordable drinking water supply. The availability of improved and quality water supply and sanitation infrastructures are widely recognized as an essential component of human rights, social and economic development. The poor and uneducated people mostly in peri-urban settlements are most in need for improved and safe drinking water, appropriate forms of sanitation and access to water for other domestic purposes. The WHO (2000) reports that polluted drinking water causes about 1.8 million people die from diarrheal diseases annually worldwide. Even though improved water sources are available, they are often far away from the beneficiary households and are located at inconvenient locations. The management system of stakeholders coupled with water quality problems and inaccessible water sources are some of the basic problems.

5.3 Materials and methods

Physico-chemical characteristics tested included the water pH, conductivity, total suspended solids, total dissolved solids, turbidity, and metal elements such as manganese, Iron, potassium, sodium and calcium. The nutrients of non-metals tested included chlorides and sulfates. The tests also examined potable water sources for bacteriological concentrations by testing for total coliforms. Physical qualities of water tests were done by in-situ procedures using the multi-meter device WTW Oxi 340i model while the chemical (both metals and non-metals) in the potable water were analyzed in the laboratory using colorimetric method with HACH DR/890 model. A bacteriological concentration of feacal coliforms was done by filtering a sample of water on an ester membrane of cellulose with a porosity of 0,45µm. The faecal coliforms were identified by counting colonies on Petri dishes incubated at 44 ^{o}C for 24 hours whereas total coliforms were identified by counting the colonies on the Petri boxes incubated at 37 ^{o}C for 24 hours.

5.4 Results and discussion

Table 9: Physico-chemical determinants of potable surface water and rain water in Kigali city

Location	sites	PH	Cond (µs/cm)	TSS (mg/l)	TDS (mg/l)	Turb (NTU)	Mn (mg/l)	Iron (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Cl (mg/l)	SO_4 (mg/l)
Gatovu	G1	6.49	212.5	11.1	231.5	24.7	0.01	0.14	0.4	3.1	14.2	52	29.1
	G2	6.44	203	9.7	244.1	17.5	0.23	0.24	0.5	2.6	15.4	84.4	28.3
	G3	6.3	227.2	14.6	228	23.1	0.02	0.2	0.44	2.8	19.6	103.3	28.7
Mean values		6.41	214.2	11.8	234.5	21.8	0.1	0.2	0.447	2.8	16.4	79.9	28.7
WHO standards 2011 surface water		6.5-8.5	<1200	50	<2100	30	4.1	0.3	5.0	20	100	250	200
STDEV		0.1	12.2	2.5	8.5	3.9	0.1	0.1	0.05	0.3	2.8	25.9	0.4
Nyabugogo River	N1	7.75	366	90	180	209	1.2	0.21	0.81	4.9	15.9	201	276
	N2	7.6	378.6	82.2	185.6	214.6	1.8	0.34	0.7	4.1	24.6	178.8	30.4
	N3	6.9	358.2	70.1	183.4	246.9	1.64	0.12	0.3	4.9	22.2	253.7	30.8
Mean values		**7.4**	**367.6**	**80.8**	**183**	**223.5**	**1.5**	**0.2**	**0.6**	**4.6**	**20.9**	**211.2**	**112.4**
WHO standards 2011 surface water		**6.5-8.5**	**<1200**	**50**	**<2100**	**30**	**4.1**	**0.3**	**5.0**	**20**	**100**	**250**	**200**
STDEV		**0.5**	**10.3**	**10.0**	**2.8**	**20.5**	**0.3**	**0.1**	**0.3**	**0.5**	**4.5**	**38.5**	**141.7**
Rain water	R1	5.9	391	17.2	32.1	198.7	8.7	0.4	0.6	4.5	44	163.2	29.7

	R2	6.4	348.9	14.3	305	179.6	0.81	0.51	0.9	6.8	50.6	129.5	30.4
	R3	6.7	374.1	12.8	299.6	201	0.79	0.23	0.9	5.6	45.4	184.7	28.8
Mean values		**6.3**	**371.3**	**14.8**	**212.2**	**193.1**	**3.4**	**0.38**	**0.8**	**5.6**	**46.7**	**159.1**	**29.6**
WHO standards 2011 surface water		**6.5-8.5**	**<1200**	**50**	**<2100**	**30**	**4.1**	**0.3**	**5.0**	**20**	**100**	**250**	**200**
STDEV		**0.4**	**21.2**	**2.2**	**156.0**	**11.7**	**4.6**	**0.1**	**0.2**	**1.2**	**3.5**	**27.8**	**0.8**

pH= potential of hydrogen, cond = electrical conductivity, TSS= total suspended solids, TDS= total dissolved solids, Turb = turbidity, Mn= manganese, Fe= Iron, K=potassium, Na= sodium, Ca= calcium, Cl=Chloride, SO4 =sulfates and Col = coliform organisms. Gatovu = samples of ground/surface improved potable water sources, Nyabugogo River = samples of unimproved ground/surface potable water sources, Rain water = samples for potable rain water by communities in Kigali city.

The Physico-chemical tests done on the three categories of water samples used by Kigali populations indicated the presence of organic substances, inorganic cationic and anionic compounds as well as the presence of micro-bacteriological organisms. Water quality parameters for improved ground/surface water tested from Gatovu sector had their levels within permissible limits of the potable water standards (WHO, 2011).

The mean values of parameters obtained from water samples (G1, G2 and G3) were compared with the permissible values set by WHO surface water. The water parameter: WHO standards 2011 ratios from improved Gatovu water sources were- PH 6.41:6.5-8.5 (decision: below permissible limits), electrical conductivity in µs/cm 214.2:<1200 (within permissible limits), TSS in mg/l 11.8:50 (within permissible limits), TDS in mg/l 234.5:<2100 (within permissible limits), Turbidity in NTU 21.8:30 (within permissible limits), Mn in mg/l 0.1:4.1 (within permissible limits), Fe in mg/l 0.2: 0.3 (within permissible limits), K in mg/l 0.447:5.0 (within permissible limits), Na in mg/l 2.8:20 (within permissible limits), Ca in mg/l 16.4:100 (within permissible limits), Cl in mg/l 79.9:250 (within permissible limits) and

SO_4 in mg/l 28.7:200 (within permissible limits). The low concentrations of pollutant loadings in the improved potable water sources indicate the reasons for appreciating the efforts of EWSA and why the city populations needed to be supplied with enough treated water other that leaving them to depend on the traditional existing water sources for domestic use.

The means of water samples (N1, N2 and N3) obtained from unimproved water source-Nyabugogo River were also compared with WHO 2011 surface potable water standards to make decisions about the levels of pollutant loadings. PH 7.4: 6.5-8.5 (within permissible limits), electrical conductivity in µs/cm 367.6:<1200 (within permissible limits), TSS in mg/l 80.6 :50 (above permissible limits), TDS in mg/l 183 :<2100 (within permissible limits), Turbidity in NTU 223.5:30 (above permissible limits), Mn in mg/l 1.5:4.1 (within permissible limits), Fe in mg/l 0.2: 0.3 (within permissible limits), K in mg/l 0.6:5.0 (within permissible limits), Na in mg/l 4.6 :20 (within permissible limits), Ca in mg/l 20.9:100 (within permissible limits), Cl in mg/l 211.5:250 (within permissible limits) and SO_4 in mg/l 112.4:200 (within permissible limits). Heavy metal and micro metal elements presence was notice but still are within the WHO (2011) potable water permissible limits and therefore water from Nyabugogo River is not yet threatening the lives of people. However, total suspended solids and turbidity concentrations in Nyabugogo River water were higher than the recommended concentrations for potable water by the WHO 2011 surface water standards. This rise could be from organic wastes reaching the river from different sources of human activities around the city. Not all the heavy metals and non-metallic elements in the river water were analyzed; the researcher regards these as extraneous variable pollutants which may account for pollution of such water sources.

The means of water samples from rain water (R1, R2 and R3) for parameters were compared with WHO 2011 potable water standards to make decisions about the limits of pollutant loadings. PH 6.3: 6.5-8.5 (within permissible limits), electrical conductivity in µs/cm 371.3.6:<1200 (within permissible limits), TSS in mg/l 14.8:50 (within permissible limits), TDS in mg/l 212.2:<2100 (within permissible limits), Turbidity in NTU 193.12:<30 (above permissible limits), Mn in mg/l 3.4:4.1 (within permissible limits), Fe in mg/l 0.38:0.3 (above permissible limits), K in mg/l 0.8:5.0 (within permissible limits), Na in mg/l 5.6:20 (within permissible limits), Ca in mg/l 46.7:100 (within permissible limits), Cl in mg/l 195.1:250 (within permissible limits) and SO_4 in mg/l 29.6:200 (within permissible limits). The concentrations of turbidity in NTU and Iron in mg/l are above the permissible limits by WHO (2011) drinking water quality. This could be attributed to the air pollution from industries that the pollutants readily mix with rain water in space.

Table 10:Bacteriological compositions of surface water improved, unimproved and rain water in Kigali city

Location	**sites**	**Coliform organisms cfu/100mls**
	G1	18.4
	G2	11.7
Gatovu	G3	15.7
Mean values		**15.3**
WHO standards 2011 surface water		**400**
Standard deviation		3.4
	N1	36.7
	N2	45.8
Nyabugogo River	N3	40.1
Mean values		**40.9**
WHO standards 2011 surface water		**400**
Standard deviation		4.6
	R1	44.1
	R2	24.8
Rain water in Kacyiru sector	R3	33.1
Mean values		**34**
WHO standards		**400**
Standard deviation		9.7

The observations made for presence of bacteriological organisms such as the coliforms for improved ground water sources 15.3 cfu/100cm, unimproved ground water sources 40.9 cfu/100cm and rain water source 34 cfu/100cm indicated low levels of concentrations of coliform organisms in all samples (Table 8). This was because the WHO standards for surface water were at 400 cfu/100cm (WHO, 2011), far higher than the recorded counts. Microbiological analysis indicated low levels of coliform bacteria were detected in Gatovu sources, Nyabugogo River and rainwater samples. There were more coliforms in unimproved water sources as compared to the rain water and improved water. Although the observed quality disparity reflected in relative parameter enrichments may be attributed, in groundwater, to natural hydrogeochemical processes and microbial contamination reflecting the unsanitary habits of the inhabitants. In rainwater, it could be related to atmospheric pollution from vehicular exhausts, industries and gas flaring by petroleum industries.

Table 11: One-Sample Kolmogorov-Smirnov Test for Normality for Physico-chemical characteristics

		PH	Cond (µs/cm)	TSS (mg/l)	TDS (mg/l)	Turb (NTU)	Mn (mg/l)	Iron (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	Cl (mg/l)	SO4 (mg/l)	Col (cfu/100mls)
Normal Parameters[a]	Mean	6.72	317.72	35.78	209.9	146.12	1.69	0.266	0.61	4.37	27.98	150.1	56.90	30.04
	Std. Dev	0.62	78.76	34.18	81.28	94.95	2.71	0.13	0.22	1.38	14.49	63.32	82.17	12.78
Most Extreme Differences	Absolute	0.203	0.321	0.373	0.245	0.304	0.373	0.246	0.151	0.154	0.259	0.138	0.514	0.152
	Positive	0.203	0.208	0.373	0.121	0.233	0.373	0.246	0.145	0.154	0.259	0.103	0.514	0.152
	Negative	-0.149	-0.321	-0.223	-0.245	-0.304	-0.268	-0.126	-0.151	-0.101	-0.199	-0.138	-0.364	-0.150
Kolmogorov-Smirnov Z		0.609	0.962	1.120	0.736	0.913	1.118	0.739	0.453	0.461	0.777	0.413	1.541	0.457
Asymp. Sig. (2-tailed)		0.852	0.313	0.163	0.651	0.374	0.164	0.646	0.986	0.984	0.582	0.996	0. 17	0.985

a. Test distribution is Normal, n= 9, p 0.05

Table 12: A Pearson linear matrix correlation coefficient for Physico-chemical and bacteriological Counts in the potable water used by populations in Kigali city.

PH	cond	TSS	TDS	Turb	Mn	Iron	K	Na	Ca	Cl	SO4	Col (cfu/100mls)	PH
PH	1.000												
Cond	0.350	1.000											
TSS	0.887**	0.511	1.000										
TDS	0.087	-0.329	-0.282	1.000									
Turb	0.442	0.969**	0.618	-0.271	1.000								
Mn	-0.332	0.534	0.001	-0.859**	0.417	1.000							
Iron	-0.230	0.418	-0.182	-0.059	0.278	0.420	1.000						
K	0.298	0.525	0.075	0.344	0.416	-0.026	0.616	1.000					
Na	0.140	0.763*	0.165	0.199	0.761*	0.157	0.532	0.692*	1.000				
Ca	-0.383	0.601	-0.340	0.062	0.482	0.439	0.740*	0.598	0.767*	1.000			
Cl	0.494	0.821**	0.703*	-0.276	0.907**	0.285	-0.050	0.166	0.547	0.219	1.000		
SO4	0.639	0.237	0.601	-0.141	0.256	-0.065	-0.160	0.340	0.151	-0.310	0.308	1.000	
Col	0.426	0.914**	0.655	-0.567	0.905**	0.609	0.208	0.224	0.476	0.324	0.811**	0.203	1.000

***. Correlation is significant at the 0.01 level (2-tailed) and /or *. Correlation is significant at the 0.05 level (2-tailed).*

PH = potential of hydrogen, Cond. =electrical conductivity, TSS =total suspended solids, TDS =total dissolved solids, Turb.=turbidity, Mn = manganese, Fe = Iron, K =potassium, Na =sodium, Ca =calcium, Cl =chlorides, SO4 =sulfates, and Col.=coliform organisms.

The design of the data for the quality of potable water sources in Kigali city was not significantly different from normal (df =9, p 0.01 or p 0.05, 2-tailed, t-test). Calculated values were of p for the existing parameters were PH=0.852, electrical conductivity 0.313, TSS 0.163, TDS 0.651, Turb. 0.374, Mn 0.164, Fe 0.646, K 0.986, Na 0.984, Ca 0.582, Cl 0.996, SO_4 0. 17 and coliforms 0.985, thus the data showed no violation of normality, linearity or homoscedasticity (Tables 9 & 10).

A Pearson product moment correlation coefficient matrix was run to determine the relationships between individual parameters that make up the water quality used by communities in the four sectors of Kigali city in which +1 was considered a positive perfect correlation while −1 was a perfect negative correlation for the linkage of household use of safe water sources. Results on Pearson linear correlation coefficient on Physico-chemical parameters are shown in Table 10. PH was strongly associated with (TSS r=0.887 and moderately with SO_4 r=0.639), electrical conductivity (cond.) was positively influenced strongly by (turbidity r=0.969, Na r=0.763, Cl r=0.821 and coliform organisms r=0.914), total dissolved solids TDS and total suspended solids TSS were associated moderately positive with (Cl r=0.703, SO4 r=0.601 and coliforms r=0.655), sodium/potassium r=0.692 moderately associated positive, sodium/ calcium r=0.767, potassium/Iron r=0.616 and calcium/Iron r=0.740. Salinity of water was moderate and depended on the sodium/chloride association of 0.547 while there was a strong positive association between chlorides and total coliform organisms (r=0.811).

Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride and sulphates, anions (ions that carry a negative charge) and/or cationic compounds (those that carry positive charges) such as sodium, calcium, iron, and manganese and potassium. TDS, TSS, CL, SO4, Coliforms were all associated with turbidity of the water, suggesting that each paired element have identical source or chemical phenomena (Singh *et al.,* 2002; Nyangababo *et al.,* 2005b as cited by Sekabira *et al.*, 2010).

Bacteriological counts shown in Table 10 indicated that Total coliform organisms were more determined or associated with (electric conductivity of the water r=0.914, TSS r=0.655, turbidity r=0.905, manganese r=0.609 and chlorides r=0.811), although a weird relationship in bacteriological counts and TDS r=-0.567 existed. "If sewage is present in water, pathogenic or disease-causing organisms could have been present in large counts and could affect consumers by causing diseases such as diarrhea; typhoid fever and even death can occur as revealed in the report of (UNEP, 2011) and (WHO, 2011)".

5.5 Conclusion

The overall opinion of consumers/communities in Kigali city on the quality of the drinking water gave a positive response that the quality was still good, although they observed that if diseases are arising from the water used, and then it could contribute literally to a small percentage of not more than 15%. There are other extraneous variables that the scope of this study or assessment could not cover that are responsible for several illnesses. Overall, 69% judged the quality of the water as being good, 22% reported of the water having some particles inside; 4% were of the view that the water was coloured especially that fetched from Nyabugogo River whilst some 3 % said the drinking water had some bad odour or smell. Provision of water in urban areas especially in the developing world faces serious problems. The major causes of water crisis reported by the residents in the study area include fast expansion of Kigali city and population of humans.

The researcher is optimistic that this study survey has yielded some useful information, which is expected to help improve water supply delivery in the study area. Consumers' perception on the level of scarcity of water; impacts of the water supply problem; cost of the water, and others will all help the officials to address these urgent issues faced by their valued customers. As the gap between demand and supply is rapidly increasing from day to day and EWSA needs to improve its infrastructures so as to be able to meet the rapidly increasing water supply needs of the study area unless other investments are put in place to augment the water supply system.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATONS

6.1 Conclusion

In Kigali city, the aggregate access to potable water masks regional inequalities. People living in suburban areas, the urban poor communities face exclusion from improvements.

According to the results obtained in the research, most of the households in selected sectors of Kigali City, 21.4% people had water connection at their home and the 78.6% have no tap water connection in their home. The households, who walk the distance below 100 m, are 22.45% of surveyed people, where 63.7% of them are those who have water connections in their homes. The 15.31% walk the distance between 100 m and 500 m to get water and most of the surveyed households (30.61%) walked between 500 m and 1 km, and more than 1km , (31.63% of them), whereas the Rwanda vision 2020 envisages having 80% of households have access to drinking water within convenient distance in 2015.

Lack of safe potable water is not significantly related to unimproved systems of Kigali water infrastructure but poor investment in water infrastructure distribution and not take account of rain water harvesting and management in Kigali City.

The results of research were based on survey and laboratory experiments of sampled water. Even if water sources are polluted as far as all the bacteriological characteristics are generally indicating high concentrations in relation to the standards requirements by WHO/REMA, the researcher can conclude that there are no bacteriological and heavy metal contaminants in potable ground water sources and rain water used in Kigali city but the mode of collection treatment are other source of water pollution in Kigali.

The non availability of access to drinking water causes the problem of losing time to generate income activities whereas the insanitation generating the different diseases. Therefore, according to the research findings in urbanized areas of selected Sectors of Kigali city, the accessibility to drinking water is not adequate referring to international indicators of drinking water accessibility.

6.2. Recommendations

a) **To Government**

- Support programs to improve economic efficiency in the water sector and assists all private companies in charge of water supply.
- Managing water services in an efficient way, by providing sizable subsidies to the water sector, by adopting a social price for water or by providing targeted aid for water.
- The government should provide that low income group with support so that they have access to cleaned water at affordable price.
- In the aim alleviating the financial burden for the poorest part of the rural center, the districts should keep a list of vulnerable households (widows, poor single-parent households), so that they could get free access to water points. These lists may be drawn up by local communities and approved by local authorities.
- Gravity water systems need to be constructed from the highlands of Virunga to low altitude areas of Kigali city by pressure levels.

b) To the public and private institutions in charge of water related issues.

- Adapt the price of water to low-income groups' ability to pay which consist in lightening the burden on small consumers (for instance by increasing the price paid by large consumers and non-domestic consumers). This company has to remember that its functionalities is under Rwanda government's objectives and the governments' objective is that everyone has access to water, not that everyone pays the same price per m^3 as if it were an average commodity.

- Improve their customer care for instance by providing customers with the simple and efficient way of paying for water bill for instance instead of paying only at the office customers should pay on bank account and transfer only a payment slip.
- That project should provide as many public water taps as possible especially in newly settled zones because water is a basic need.
- Facilitate private water connection in dwellings in order to attract consumers which are their clients.

REFERENCES

Antony C. (2000); WILBRAHAM, Dennis D. Staley Michael s. MATTA, EDWARD.L.WATERMA). Chemistry. New York.

Ashton, P.J. *et al.* (2001), An overview of the impact of mining and mineral processing operations on water resourcesand water quality in the Zambezi, Limpopo and Olifants catchments in southern Africa: Contract report to the mining, minerals and sustainable development (Southern Africa) project. Pretoria: CSIR Environmental.

Beukman, R. (2002), 'Revisiting local water management in southern Africa'. Paper prepared for Policy workshop on local water management. Ottawa: Canada. 18 - 19 March 2002.

Cap-Net. (2009), *Tutorial on basic principles of integrated water resources management. page 5 of 38*. Available on www.cap-net.org CHRA website. http://www.chra.co.zw and https://www.google.com/#q=Cap-Net+(2009).pdf. Accessed in July 2013.

COHRE, AAAS, SDC and UN-HABITAT. (2008), *Manual on the right to water and sanitation: A tool to assist policy makers and practitioners develop strategies for implementing the human right to water and sanitation.* Geneva: Centre on Housing Rights and Evictions.

Dusingizumuremyi, E. (2007). Impacts of inadequate sanitation and unsafe drinking water on human health: A case study of Kigali City, the capital of Rwanda. WHOCC News letter, No. 12

DWAF (Department of Water Affairs and Forestry). (2001), *Water and sanitation.*

EWSA (Energy water and sanitation Authority). (2013), Countrywide water supply status and projects to increase , access, Kigali, Rwanda Available on www.ewsa.rw, accessed in July 2013

Gobarchev/Law, B.I. (2005), *Potable reuse: What are we afraid of?* IBL Solutions.

GWP (Global Water partnership). (2000), Integrated water resources management, Global Water partnership, Stockholm.

MININFRA. (2010), National Policy & Strategy for Water Supply and Sanitation Services, February 2010, Kigali, Rwanda

MINIRENA (Ministry of Natural Resources). (2011): Water resources management sub-sector strategic plan (2011 – 2015). Kigali, Rwanda

MINITERE. (2004), Ministry of Lands, Environment, Forests, Water, and Natural Resources Sectoral Policy on Water and Sanitation.Kigali,

Mugenda Olive M. and Mugenda G. Qbel. (1999), Research Methods: Quantitative and Qualitative Approaches, Nairobi, Acts Press

National University of Rwanda (NUR). (2002). the pollutants from Rwanda waters and their impacts on the regional environment .National University of Rwanda research committee. Kigali, Rwanda.

NCS (National Census Service). (2002), General Census of population and housing, Ministry of Finance and Economic Planning, Kigali, 2002.

Nilson D. (2006), A heritage of sustainability; Reviewing the origin of the large scale water and sanitation systems in Kampala Uganda, journal of Environment and Urbanization, (18), (2), 369-385.

Oxford advanced learners dictionary. (1995), Oxford University press, available in *www. http://en.wikipedia.org/wiki/Oxford_Advanced_Learner's_Dictionary.*

RDG (Rwanda Development Gateway) (2007). Demography and Economy of Rwanda, Kigali, Rwanda . http: www.rwandagateway.org/article.php3, id_article=137. Accessed, August 20, 2013

REMA. (2009): Rwanda State of Environment and Outlook Report, Kigali, Rwanda Environment Management Authority, P.O. Box 7436 Kigali, Rwanda http://www.rema.gov.rw/soe/

SANO, J.C. (2007). Urban environmental infrastructure in Kigali: challenges and opportunities for modernised decentralised sanitation systems in poor neighbourhoods. August, 2007; Msc. thesis environmental sciences Wageningen University, Netherlands, 126p.

Sekabira K. ; Oryem Origa ., Basamba T. A.; Mutumba; E. Kakudidi. (2010), Assessment of heavy metal pollution in the urban stream sediments and its tributaries, Kampala, Uganda, 2010, p441(7)

Sekomo, C.B., Nkuranga, E, Rousseau,D.P.L. and Lens, P.N.L. (2010). Fate of heavy metals in an urban natural wetland: The Nyabugogo Swamp (Rwanda). Water Air Soil Pollut (2011):321-333. [On line]. Available at http:// www.springerlink .com/ content /227 0548840x87281/. [Accessed on 15 December 2011].

Umuhoza, M, F.A, Nhapi, I, Wali, U.G and Bannada, N.(2010). Assessment of wastewater management practices in Kigali City, Rwanda. The Open Environmental& Biological Monitoring Journal, 2010, 3, 21-27.

UN (United Nations). (2003); The UN World Water Development Report - Water for People, UNESCO and Berghan Books, Barcelona.

UN (United Nations). (2012); Millennium Development Goals, 2012; United Nations, New York, 2012, p3

UNEP (United Nations Environment Programme). (2011). Rwanda: From Post-Conflict to Environmentally Sustainable Development. United Nations Environment Programme, Nairobi, Kenya. p171-196.

UNESCO (United Nations Educational Scientific and Cultural Organization). (2003). Water for people, water for Life : United Nations World Water Development Report, Paris.

UNESCO (United Nations Educational Scientific and Cultural Organization). (2006), A shared responsibility: The UN-World water development report 2.Paris: UNESCO/ New York: Bergman books, Journal for natural sciences.

UN-Habitat. (2003), Slums of the world: The face of urban poverty in the millennium.

United Nations Habitat. (2003b), *Water and Sanitation in the World's Cities: Local Actions for Global Goals,* Earthscan Publication Ltd, London; Chapter 5 with Gordon McGranahan: 'Changing Perspectives and Roles in Urban Water and Sanitation Provision – Privatization and Beyond', pp. 158-192.

Van Vuuren, L., (2010), Time is running out as Africa sprints towards Mellenium development goals deadlines. The water wheel 9 (1): p 125-27.

WHO (World Health Organization). (1999); The world health report 1999: Making a difference. 1211 Geneva 27, Switzerland

WHO (World Health Organization). (2000), Development of Indicators for Monitoring Progress towards Health for All by the Year 2000. Geneva, WHO, p. 40.

WHO (World Health Organization). (2003); The Global Water Supply and Sanitation Assessment, Geneva, 2003, [http://www.who.int/docstore/water_sanitation_health/Globassessment/Global TOC.htm], (accessed on 14 January 2013).

WHO (World Health Organization). (2003); The Right to Water, WHO, Geneva. http://wrmin.nic.in/policy/nwp 2002.pdf.

WHO (World Health Organization). (2004), Guidelines for drinking water quality, 3rd ed. [Online]. Available at http://www.who.int.water_sanitation_health. [Accessed on 12th November, 2012].

WHO (World Health Organization). (2006) and UNICEF (2006); Meeting the MDG: Drinking water and sanitation target: Joint Monitoring. http://who.int/water_sanitation_health/monitoring/jmpfinal.pdf (accessed in February 2013).

WHO (World Health Organization). (2011), Guidelines for drinking-water quality; incorporating first addendum. Library Cataloguing-in-Publication Data, Vol. 1, Recommendations. 3rd ed.

WHO (World Health Organization). (2011); Permethrin in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/ WSH/05.08/111/Rev/1).

APPENDICES

Appendix 1: Transmittal Letter

KAMPALA INTERNATIONAL UNIVERSITY

EXPLORING THE HEIGHTS

Ggaba Road, Kansanga
PO BOX 20000 Kampala, Uganda
Tel: +256-414-266813
Mob+256-701 688552
Fax: +256-414 501974
E-mail: admin@kiu.ac.ug
Website: www.kiu.ac.ug

OFFICE OF THE HEAD

DEPARTMENT OF BIOLOGICAL & ENVIRONMENTAL SCIENCE,
COLLEGE OF APPLIED SCIENCE & TECHNOLOGY (CAST)

Date: 18th March, 2013

Dear Sir/Madam,

RE: REQUEST FOR BIMENYIMANA THEONESTE MEM/37095/121/DF TO CONDUCT RESEACH IN YOUR ORGANISATION

The above mentioned is a bonafide student of Kampala International University pursuing a Masters Degree course in Environmental Management & Development.

He is currently conducting research for his dissertation entitled "**Assessment of Urban Potable Water Availability and Accessibility in Kigali City.**"

Your organization has been identified as a valuable source of information pertaining to his research project. The purpose of this letter is to request you to avail him with the pertinent information he may need.

Any information shared with him from your organization shall be treated with utmost confidentiality.

Any assistance rendered to him will be highly appreciated.

Yours truly,

Sande

18 MAR 2013

Eric Sande (**PhD**).
Head of Department

"Exploring the Heights"

Appendix 2 :Authorisation for Conducting a Research in Kigali City

Republic of Rwanda
City of Kigali

Ref n°: 2366../07.01.07/13

Kigali, 24/07/2013

Théoneste BIMENYIMANA
Kigali-Rwanda

<u>Re</u>: Authorisation to conduct a research in the City of Kigali

Reference is made to your letter dated 20th June 2013 requesting for authorisation to conduct a research in the City of Kigali;

Reference is also made to Kampala International University letter dated 18th March 2013;

The City of Kigali, hereby, gives you the authorization to conduct your research. Kindly get in touch with the Director of Infrastructure who shall guide you on how to carry out that research.

Regards,

Jeanmarie 23/07/2013

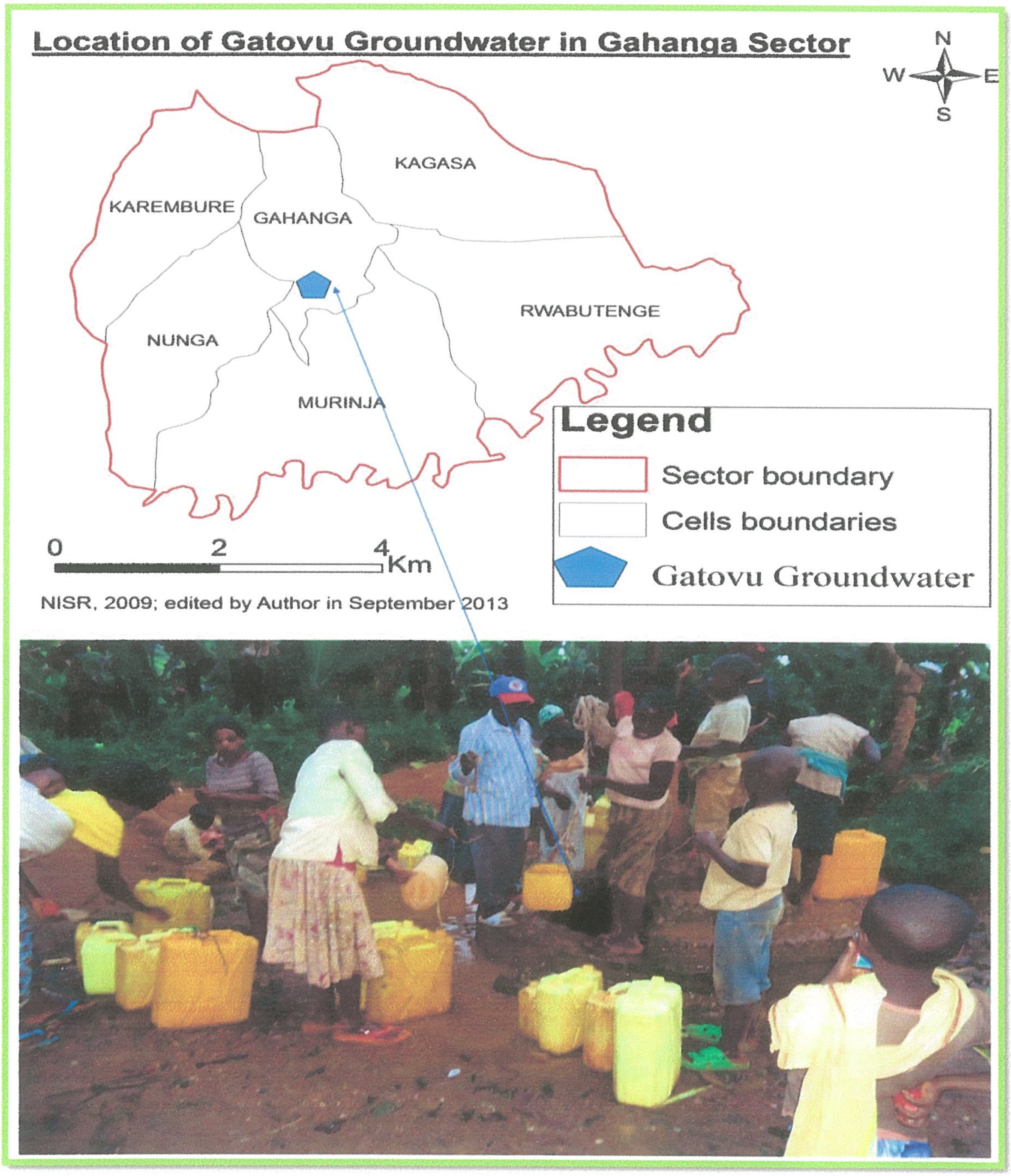
MATABARO Jean Marie
Executive Secretary, City of Kigali

<u>Cc</u>

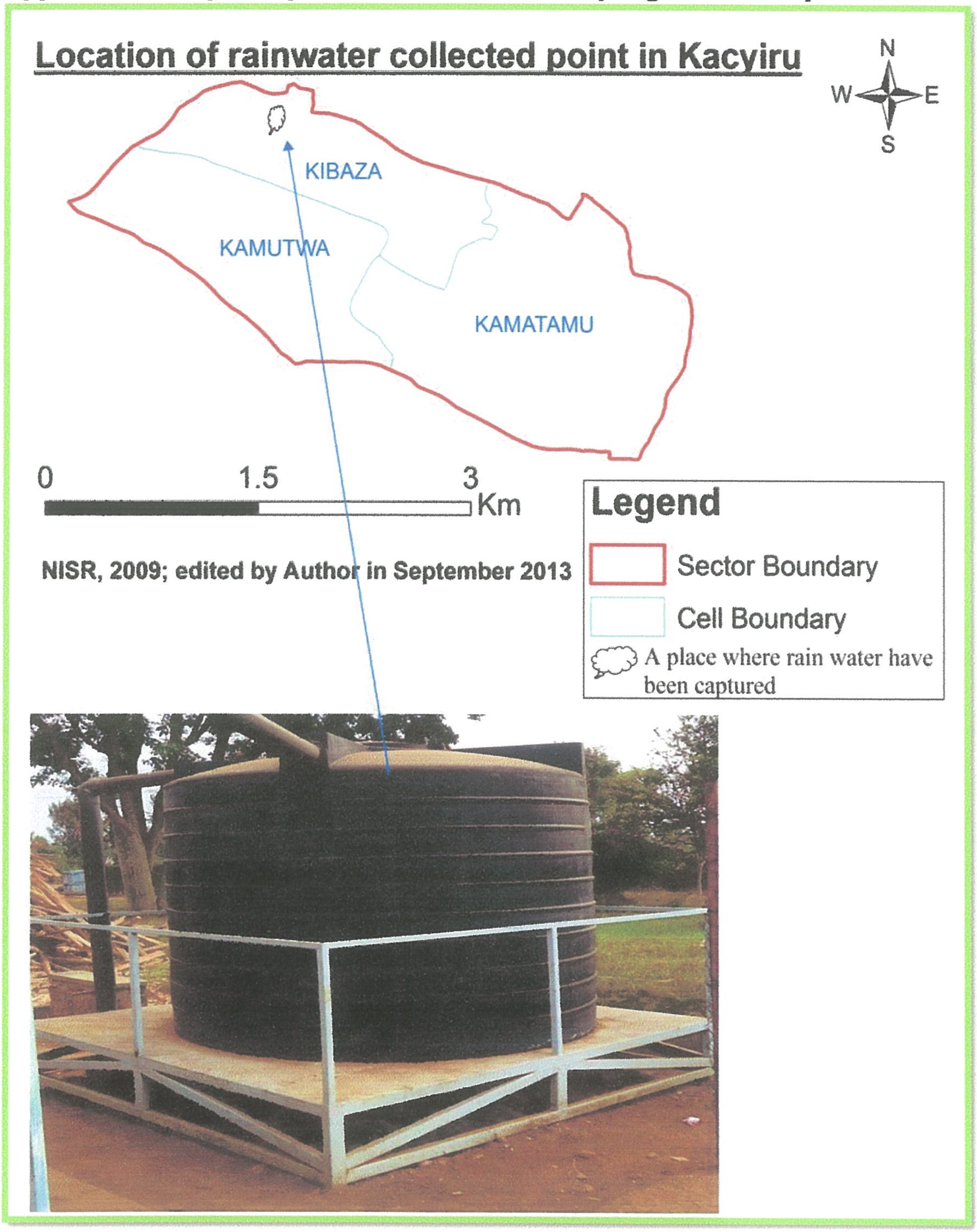
- His Worship the Mayor, City of Kigali;
- Vice Mayors;
- Director of Human Resources and Administration;
- Director of Infrastructure
  <u>KIGALI</u>

City of Kigali, B.P.3527 Kigali, Tél 250-57-2255 57-6967 57-5958 & Fax 250-57-3684 www.kigalicity.gov.rw

Appendix 3: Map and photo of Gatovu ground water location



Appendix 4: Map and photo of rain water sampling site in Kacyiru sector



Appendix 5: Transmittal letter for the respondents

Dear Sir/ Madam,

Greetings!

I am a post graduate candidate for the award of Masters of Science in Environmental Management and Development of Kampala International University and currently pursuing a research study titled: **"Assessment of Urban Potable Water Availability and Accessibility in Kigali City, Rwanda".**

In view of this empirical investigation, may I request you to be part of this study by answering my questionnaire? You are requested to kindly answer the questions below with honesty is not an examination where answers have been marked wrong or right. Rest assured that the information you provide shall be kept with utmost confidentiality and have been used for academic purposes only. Please respond to all of the items in the questionnaire and do not leave any item unanswered.

The completion of this research work is a key for my Masters completion.
Further, I request to retrieve the questionnaires within five days from the date of distribution.

For any difficulty, my contacts are +250788667483 and E_mail: tbimenyi@gmail.com

Yours faithfully,

BIMENYIMANA Théoneste

Appendix 6: Clearance from ethics committee

Date_______________

Candidate's Data

Name______________________________________

Reg. Number ______________________________________

Course ______________________________________

Title of Study ____

____

Ethical Review Checklist

The study reviewed considered the following:

___ Physical Safety of Human Subjects

___ Psychological Safety

___ Emotional Security

___ Privacy

___ Written Request for Author of Standardized Instrument

___ Coding of Questionnaires/Anonymity/Confidentiality

___ Permission to Conduct the Study

___ Informed Consent

___ Citations/Authors Recognized

Results of Ethical Review

___ Approved

___ Conditional (to provide the Ethics Committee with corrections)

___ Not approved/ Resubmit Proposal

Ethics Committee (Name and Signature)

Chairperson ______________________________

Members ______________________________

Appendix 7: Informed Consent

I am giving my consent to be part of the research study of Mr. Théoneste BIMENYIMANA that will focus on: **"Assessment of Urban Potable water Availability and Accessibility in Kigali City, Rwanda".**

I shall be assured of privacy, anonymity and confidentiality and that I have been given the option to refuse participation and right to withdraw my participation anytime.

I have been informed that the research is voluntary and that the results have been given to me if I ask for them.

Initials:

Date:

Appendix 8: Research Instrument

Direction: -*Tick to the suitable answer, if possible many answers are allowed.*

-Please give details for open question

Appendix 8.1. Interview Guide/Questionnaire for Householder

Section I: Identification

1) Names: (Optional): ....
2) Gender (please specify): Male : ☐ Female: ☐
3) Age (Please specify):Under 15: ☐ ;15-35:☐; 35-45: ☐; above 45 years: ☐
4) Sector............................... District........................
5) What is the size of your family?

a.1 person: ☐ b. 2-3 people: ☐ c. 4-6 people: ☐ d. above 6 people: ☐

6) Level of education: None: ☐
   Primary: ☐
   Secondary: ☐
   University: ☐
7) Employment:
   State employee ☐ Specify....................................
   Private employee ☐ Specify....................................
   NGOs' employee ☐ Specify....................................
   Religious employee ☐ Specify....................................
   Others ☐ Specify....................................

Section II: Existing situation mode of potable water supply

8) Which kind of water source are you using?

a. Public aquadinamic Piped water (public tape) ☐
b. Private drinking water connection in dwelling ☐
c. Protected spring ☐
d. Unprotected spring ☐
e. Nyabugogo river or other river water resource: ☐ Specify which river........
f. Rain water tanks ☐
g. Roof rain water ☐

10. From the time you settled here safe potable water availability is

- Increasing ☐
- Decreasing ☐
- Remain the same ☐

Section III: Potable Water Availability and Accessibility

11) a. Are you connected to the tap water from EWSA?

i. Yes ☐
ii. No ☐

b. If not, why don't you have water connection in your home?

a. We cannot afford bills from EWSA ☐
b. It is difficult to fulfill the requirements for being a subscriber of EWSA
c. I am satisfied with water I get from other sources ☐
d. Others ☐ Specify ....

12) How do you get potable water?

a. We buy water from the neighbourhood ☐

b. We buy water from public standpipes of EWSA ☐

c. We fetch water from protected boreholes ☐

d. We fetch water from unprotected boreholes ☐

e. We fetch water from wetlands, rivers and ponds ☐

f. Others (specify).................................. ☐

13) How much time do you spend to reach potable water?

a. Below 20 minutes ☐

b. Between 20 and 30 minutes ☐

c. Between 30 and 45 minutes ☐

d. Between 45 and 1hour ☐

e. Above 1 hour ☐ Try to specify...........

14) How many meters do you walk to reach water?

a.Below 100m ☐

b. Between 100m and 200m ☐

c. Between 200m and 500m ☐

d. Between 500m and 1Km ☐

e.Above 1 Kilometer ☐ Specify.................

15) Once you reach a water source, how much time do you take waiting to fill a Jerrycan[1]?

a. Under 5minutes ☐

b. Between 5 and 20 minutes ☐

c. Between 20 and 30 minutes ☐

d. Above 30 minutes ☐ Try to specify..............

---

[1] *A **jerrycan** (also written as jerry can or jerrican) is a robust fuel container originally made from pressed steel. It was designed in Germany in the 1930s for military use to hold 20 litres of fuel. Even in Rwandan culture, a jerrycan is used as a holding of 20 liters of liquid. In this research, a jerrycan of water is a holder of 20liters of water.*

Section IV: Potable Water Affordability

16) What is the quantity (number of Jerrycans) is your family's daily water consumption?

a. Below 2 Jerrycans ☐

b. Between 2 and 5 Jerrycans ☐

c. Above 5 Jerrycans ☐

17) Is potable water free of charge in your home?

a. Yes ☐ b. No ☐

18) If charged, how much does a jerrycan (20 liters) of potable water cost?

a. Under 20Frws ☐ b. Between 20 and 50Frws ☐

c. Between 50Frws and 100Rfws ☐ d. Above 100Frws ☐

19) If you pay a monthly/annual contribution, how much is it? ☐

20) a) Do you have any contribution for creation or maintenance of water infrastructure?

i.Yes ☐ ii. No ☐

b) If yes, i) How much do you pay per month? ☐

ii) According to you, is it easy for you to get such funds?

a. Yes ☐ b. No ☐

iii)Are you ready to increase your contribution to improve water supply?

a. Yes ☐ b. No ☐

21. i. Is there any support provided to poor households in order to pay that domestic water tax? a. Yes ☐ b. No ☐

iii. If yes, specify ....

Section V: Evaluation of Rainwater harvesting and management

22) Do you sometimes use rainwater?

i. Yes ☐

ii. No ☐

23) If not, why do not you use rainwater?

i. We do not need it because we have enough water ☐

ii. We do not have financial mean to collect it ☐

iii. It is no important to use it ☐

iv. Others ☐ Specify.........................

24) If you use rainwater sometimes, what system do you use for collecting it?

a. We have a rainwater reservoir ☐

b. We get it through a closed way system on the roof ☐

c. We get it through the roof only ☐

d. Other means ☐ Specify..................................

25) In which activity do you use this rainwater?

a. We use the rain water in all household requirements ☐

b. We use rainwater for washing and in gardens ☐

c. Others ☐ Specify ....

Section VI: Effect of Safe Potable Water Shortage

26) How do you clean the water to consume?

a. We drink without cleaning ☐

b. We boil it ☐

c. We use Sur' eau (Chemical Products) ☐

d. Others ☐ Specify ....

27) In which period of the year do you predominantly face potable water scarcity?

a. Short rain season ☐ b. Short dry Season ☐

c. Long dry season ☐ d. Long rainy season ☐

28) What are consequences of lack of safe potable water you face in your family or your region?

a. Poor hygiene ☐

b. Frequent illness ☐

c. None ☐

d. Others ☐ Specify ....

29) In case of water scarcity, how do you get water to use?

a. Water pond ☐ b. River water source ☐

c. Wetlands water ☐ d. Others ☐ Specify.........................

30) What are problems for children and women from potable water scarcity in Kigali?...

....

31) What are your suggestions to solve these problems? ....

....

32) Any other comment? ....

....

Thanks!

4. What are activities done or planned by the government/your institution in order to solve the problem of water scarcity in urban areas? ....

....

a) Are they implemented regularly in this region? Yes ☐ No ☐

b) If not well done, why?

i) Low income of population ☐

ii) High cost of potable water in Kigali City ☐

iii) Insufficient water resources in Kigali ☐

iv) Ignorance about water harvesting and management ☐

v) The number of people exceed the existing water infrastructure ☐

vi) Others ☐ Specify ....

....

5. i) Are there problems noticeable related to the lack of safe potable water to the people of Kigali City? a. Yes ☐ b. No ☐

ii) If yes, what are the main challenges faced by Kigali Communities related to lack of safe potable water in Kigali? ....

....

7) Give your suggestions for solving challenges faced by urban communities in founding potable Water in Kigali City. ....

....

8) Any other comment? ....

....

Thanks!