THE STATUS OF DRINKING WATER AT GACHAGI INFORMAL SETTLEMENT IN THIKA SUB-COUNTY, KIAMBU COUNTY, KENYA

By

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DECLARATION

This is my original work and has not been presented to any institution for the award of any degree certification.

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DEDICATION

Special dedication to my beloved mother Tabitha Wairimu, my husband Dominic Ngigi, my children Samuel and Grace, and my sisters Jane and Beth for their great encouragement, moral support and prayers throughout the study.

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I'm grateful to my supervisors Dr. Cecilia M. Gichuki and Dr. Daniel G. Manguriu for their guidance, patience, encouragement and relentless professional advice while undertaking my research thesis work. Special thanks go to all the members of the Department of environmental Science and Education under the leadership of the Dean Dr. Koske for their great support.

ABSTRACT

As a result of rapid urbanization in developing countries, majority of urban residents live in slums often characterized by lack of basic services, such as water and sanitation. The urban poor often use shallow pit latrines and at the same time may draw water from the nearby wells which is often polluted. This study explored the perception and status of drinking water in Gachagi informal settlement in Thika Municipality, Kiambu County. The study adopted both quantitative and qualitative research design to collect data. This cross-sectional study involved one hundred and forty (140) respondents. The respondents age ranged from 18 years to 68 years, the mode was 29 years, median 38 years and the mean age were 40.9 ± 3.40. Twenty water (20) samples were collected from various water sources used by the respondents and used for laboratory analysis. Of these twenty, ten were from shallow ponds and rocks (aquifers), five from the municipal water-tap and five from borehole. Multiple tube fermentation technique was used to enumerate coliform bacteria. The collected data was statistically analyzed with qualitative data undergoing thematic analysis and results discussed and presented in graphs, charts, frequency tables and pie-charts. The common sources of water were municipal-taps (n=59), shallow wells (n=35), water-ponds (n=33), River Chania (n=7), boreholes (n=3), rain water and (n=84) transported water using open buckets with no lids. Age (p=0.011), gender (p=0.020) and level of education (p=0.046) of respondents had significant association with method of water transportation. At least (n=30) of females and (n=11) of respondents with tertiary education perceived the water is contaminated with all water samples tested indicated presence of coliforms bacteria. Fecal Coliforms bacteria were present in all the tested water with sites indicating high risk. Escherichia coli (E. coli) bacteria were also found to be present except in municipal tap water. Majority (n=91) of respondents were aware of water treatment methods with boiling of water (n=46) and chlorination (n=19) being commonly used method. More than three-quarter of the respondents (n=111) disclosed that they had suffered a waterborne disease especially diarrhea and there was average significant level of awareness of water-borne diseases associated with unsafe drinking water. The drinking water sources were contaminated and therefore, water projects should be up-scaled in slums. From the study it has been established that water in slums is not safe for drinking. The government and other development agencies should therefore strive to enhance the availability of safe water in the slums.

TABLE OF CONTENTS

DECLARATION ..... **ii**
DEDICATION ..... **iii**
ACKNOWLEDGEMENT ..... **iv**
ABSTRACT ..... **v**
TABLE OF CONTENTS ..... **vi**
LIST OF TABLES ..... **ix**
LIST OF FIGURES ..... **x**
LIST OF ABBREVIATIONS AND ACRONYMS ..... **xi**

CHAPTER ONE: INTRODUCTION **1**
1.1 Background of the Study 1
1.2 Statement of the Problem 3
1.3 Objectives of the Study 4
1.4 Research Questions 4
1.5. Hypotheses 4
1.6 Justification of the Study 4
1.7 Conceptual Framework 5
1.8 Scope of the Study 7
1.9 Definitions of Operational Terms 8

CHAPTER TWO: LITERATURE REVIEW **9**
2.1 Introduction 9
2.2 Location of Informal Settlements 10
2.3 Sources of Water for Domestic Uses in the Slums 10
2.4 Composition of the Mineral Content that Pollutes the Water 10
2.5 Types of Water Borne Diseases 11
2.6 Policy Framework 13
2.7 Knowledge Gaps 14

CHAPTER THREE: RESEARCH METHODOLOGY **15**
3.1 Introduction 15
3.2 Area of the Study 15
3.3 Study Design 17
3.4 Target Population 17

3.5 Sample Size....17
3.6 Sampling Procedure....18
3.7 Instruments for the Study....19
3.8 Data Collection Procedures....19
3.8.1 Interviewer administered questionnaire....19
3.8.2 Direct Observation....19
3.8.3 Water Analysis....19
3.9 Data Analysis....20
3.10 Logistical and Ethical Consideration....21

CHAPTER FOUR: RESULTS AND DISCUSSIONS....22
4.1 Introduction....22
4.2 Questionnaire Response Rate....22
4.3 Demographic Characteristics of the Respondents....22
4.3.1 Age....22
4.3.2 Gender....23
4.3.3 Level of Education....23
4.3.4 Occupation of Respondents....24
4.3.5 Length of Stay at Gachagi Informal Settlement....24
4.4 Domestic Water used in Gachagi Informal Settlement....25
4.4.1 Sources of water in Gachagi informal settlement....25
4.4.2 Transportation of Water....26
4.4.3 Socio-Demographic Characteristics with Transportation of Water....27
4.5 Types and Sources of Water Contaminants....28
4.5.1 Perception of drinking water....28
4.5.2 Source of Contamination....29
4.5.3 Comparison of Various Sources and Types of Pollutant....30
4.5.4 Use of latrines by adults and children....31
4.5.5 Water Analysis....32
4.6 Methods of Water Treatment....33
4.6.1 Awareness and use of various methods of water treatment....33
4.6.2 Socio-Demographic Characteristics with Treated Drinking Water....34
4.6.3 Environment Cleaning....35
4.7 Link between Level of Awareness and Water Contaminants....37

4.7.1 Level of Awareness....37
4.7.2 Socio-Demographic with Level of Awareness....38
4.9 Hypothesis Testing....39

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS 41
5.1 Introduction....41
5.2 Summary....41
5.2.1 Sources of Drinking Water....41
5.2.2 Types and Sources of Water Contaminants....41
5.2.3 Awareness and Use of Various Methods of Water Treatment....42
5.3 Conclusion....43
5.4 Recommendations....44
5.5 Suggested Areas for Further Research....44

REFERENCES....45
APPENDICES....50
Appendix i: Questionnaire....50
Appendix ii: Consent....53
Appendix iii: Key Informant Interview Guide....56
Appendix iv: Plates....58
Appendix v: Graduate School Authorization....59
Appendix vi: NACOSTI Permit....60
Appendix vii: Kiambu County Authorization....61
Appendix viii: Ministry of Education-Kiambu County Authorization....62

LIST OF TABLES

Table 2. 1: Guidelines for using water with known nitrate content. 11

Table 2. 2: Organisms and associated waterborne diseases 13

Table 4. 1: Questionnaire response rate 22

Table 4. 2: Distribution of respondents by age 23

Table 4. 3: Distribution of respondents by gender 23

Table 4. 4: Distribution of respondents by level of education 24

Table 4. 5: Distribution of respondents by occupation 24

Table 4. 6: Socio-demographic characteristics with transportation of water 28

Table 4. 7: Respondent's perception of drinking water 29

Table 4. 8: Comparison of Various Sources and Types of Pollutant 31

Table 4. 9: Use of latrines by respondents 32

Table 4. 10: Water analysis 33

Table 4. 11: Awareness and use of various methods of water treatment 34

Table 4. 12: Socio-demographic characteristics with treated drinking treatment 35

Table 4. 13: Environment cleaning 36

Table 4. 14: Socio-demographic with level of awareness 39

Table 4. 15 Relationship between water source and level of water contamination 40

LIST OF FIGURES

Figure1.1: Conceptual framework, ...6

Figure 3. 1: Map of the study area. Data Kenyatta University GIS Lab.....16

Figure 4. 1: Length of stay at Gachagi informal settlement 25

Figure 4. 2: Sources of water in Gachagi informal settlement 26

Figure 4. 3: Transportation of water 27

Figure 4. 4: Source of contamination.....30

Figure 4. 5: Level of awareness of link between contaminants.....37

LIST OF ABBREVIATIONS AND ACRONYMS

APHRC	African Population Health Referral Centre
M SL	Meters above Sea Level
MDGs	Millennium Development Goals
NGO	Non-Governmental Organizations
TDS	Total Dissolved Solids
UNDP	United Nations Development Programs
UN-Habitat	United Nations Habitat
USA	United States of America
UNDP	United States Agency for International Development
USAID	United State Agency for International Development
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Clean, safe and adequate freshwater is vital to the survival of all living organisms and the smooth functioning of ecosystem, communities and economies. Declining water quality has become a global issue of concern as human population grows, industrial and agricultural activities expand and climate change threatens to cause major alterations to the hydrological cycle (EPA, 2011). Water quality issues are complex and diverse and are deserving of urgent global attention and action. Both natural processes and human activities influence the quality of water sources. The development of water quality standards has made it easier to measure and determine water quality and gauge the different levels of consumption. Before water can be put to some of its uses especially domestic and industrial, it is necessary to know its quality. Therefore physical, chemical and bacteriological properties of the water are defined and in order to do this accurately, appropriate tests are carried to examine the water (UNEP, 2012).

According to a report on world development indicators by World Bank,1 1 billion people globally lack access to potable water with 2.5 billion people have inadequate sanitation facilities. Annually, 4 billion cases of water-related diseases cause 3.4 million deaths worldwide, which is a leading cause of deaths especially in children under 5 years who die of water-related diseases (World Health Organization, 2017). Slum congestion, homeless families, street children, severe water shortage, air pollution, stinking water bodies, heaps of garbage, unhygienic working conditions, are all unique to urban environment in developing countries (World Health Organization, 2017). While studying Mumbai and Pune slums, they found that slum dwellers live in a variety of circumstances, that is, on pavements, besides tracks, in swampy areas and on steep slopes and lack of proper income becomes the major factor for poor housing. The overall situation is too alarming because the degraded environment in which they live take toll on physical, mental and moral health of the dwellers (Marcellinus, 2017).

It has been found that, poor sanitation and lack of safe drinking water are the main cause of diseases like diarrhoea, typhoid and malaria, and other water borne related diseases. Biogas technology using human waste has been found to reduce pathogen in the slurry (Basllir, 2012). According to the United Nations Human **S**ettlements Program, nine

hundred and twenty-four million people lived in slums in 2001. The estimate suggests that this figure may rise to 1.5 billion by 2020 (UNEP, 2012). Though data is limited on water provision in the slums, it is suggested that these people use public water pipes, unprotected wells and springs, which does not necessary mean that safe water is available, especially in conditions of widespread ground water contamination as a result of lack of proper sanitation facilities (Kimani & Ngindu, 2010).

In many cities, access to water through private household connections from network infrastructure is substantially low and African countries are the worst (Erena, 2015). Secondly, more than two thirds of the urban population in African countries relied on water from non-residential connections; such reliance is notably high even in the few countries that recorded some improvement in all the indicators. In half of the African countries, the proportion of residential water connections either declined or was steady (Kwame, 2011). An emerging trend is that access rates to safe drinking water increased in ten to thirty Africa economies between 2010 and 2014, but this was accompanied by declining rates of direct household connections (Gholson, et al., 2018). In case of water, the gap between access in general and access via household connections is closed by a host of other providers including tanker truckers, vendor-operated water points, community managed projects public stand pipes, boreholes and wells (Marcellinus, 2017).

According to the Gu et al., (2014), 11 % of the global population or 783 million people are still without access to clean water. The world population will continue to grow and will not only affect the demand for water but also its cost. For this reason, per capita water use is expected to decline with higher population densities. It is well documented that lack of access to quality and adequate water contributes to prevalence of poverty in the society. While that source plays a crucial role where provisions from public networks are absent, the quality of their supply is far from ideal (Semey, 2014). Development in the slums concerns every aspect of Sustainable Development Goals (SDGs). Major development agencies such as the USAID and the World Bank, focused on small-scale projects in some neighborhoods, paying particular attention to infrastructure services, such as safe water and sanitation (Cosgrove & Loucks, 2015). However, it was difficult to provide these services because of fast unplanned

proliferation of informal settlement that failed to meet urban planning regulations (Allaire, et al., 2018).

There have been serious weaknesses identified in regulatory objectives, processes, capacity and the institutional environment in developing countries (Trevett, et al., 2015). In countries like Argentina, which initially attracted considerable foreign investment to its water sector through privatization, private companies fell into dispute and were eventually re-nationalized following years of disputes and renegotiations (Ziegler, et al., 2011). In the slums of Nairobi and Abidjan, more than 80% of the population rely on source other than household connections, including kiosks, water sellers and other small - scale providers (Sonal, et al., 2014). Through the vision 2030, it is targeted that by 2020, Kenya will have achieved a significant improvement in the lives of slums-dwellers while deferring new formation. The SDGs targetet a half by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation. Many slums, for example, Gachagi informal settlement situated along Thika-Garissa highway provides a case of inadequate, safe drinking water. The residents obtain their water from wells and high-risk ground water located near shallow pit latrines that might pose a high risk to the health of the slum dwellers.

1.2 Statement of the Problem

Gachagi informal settlement, located within Thika Municipality, Kiambu County, has degenerated into a slum with development of informal settlement over the last decade. When ground water and wells are used as sources of domestic water, risks of contracting water borne diseases become a reality (Rufener et al., 2010). A report by Mbaka et al., (2017) showed that infant and child mortality are particularly higher in slums, the pattern attributed to unsafe water and poor sanitation in the informal settlements. The content and level of contamination is a concern to every aspect of SDGs (Bain et al., 2014). The quality status of water collected by the inhabitants of Gachagi informal settlement is not known, the research project therefore intends to study the quality level and assess the level of awareness and link between water contaminants and water borne diseases in Gachagi informal settlement.

1.3 Objectives of the Study

The main objective of the study was to explore the perception and status of drinking water in Thika Municipality, Kiambu County, a case study of Gachagi informal settlement.

1.3.1 Specific Objectives

1. To determine the types and sources of water used by residents of Gachagi informal settlement.
2. To determine the types of water contaminants in Gachagi informal settlement
3. To determine level of awareness of the link between water contaminants and various methods of water treatment at Gachagi informal settlement.

1.4 Research Questions

i. What are the types and sources of water used by residents of Gachagi informal settlement?
ii. What are the types of water contaminants in Gachagi informal settlement?
iii. What is the level of awareness of the link between water contaminants and various methods of water treatment at Gachagi informal settlement?

1.5. Hypotheses

Ha_1 - There is a relationship between water source and level of water contamination.

Ha_2 - The community in Gachagi is aware of various methods of water treatment.

1.6 Justification of the Study

The findings of this study would assist in identification of the relationship between sources of water and level of contamination associated with the provision of quality water among the urban poor with an aim of tackling those problems in a sectarian approach, that is, not only long lasting but also self-sustaining. More importantly is the proper utilization of this important resource in curbing environmental degradation at the same time checking the water related diseases that are associated with poor hygiene and lack of clean water.

Lack of access to safe and clean water at Gachagi informal settlement is mainly caused by the increasing poverty levels, people living below the poverty line is now standing at 58.7% and those that suffer food poverty are 36.2% (Kiambu, 2014) of the population. Women and children bear the greatest burden because of their social gender role of collecting water for their households. They often walk 3 to 4 kilometres daily carrying heavy buckets of contaminated water to their homes (Kiambu County Report, 2014). They also suffer from water borne diseases, limited participation in education, income-generating activities and political issues.

Household distribution per time taken to fetch drinking water is over 60 minutes, showing that the largest proportion of the population do not have access to clean drinking water, but rather rely on unimproved water supplies (Kiambu County Report, 2014). Furthermore, there is limited information about water demand and distribution in Gachagi informal settlement, water use management strategies and the proportion of population without sustainable access to safe drinking water.

The wells, boreholes and river are highly polluted with animal waste, soil and solid waste. The water crisis in the study area is attributed to the wave of drought, catchment degradation and population growth which has negatively impacted on the economic activities of the local communities. The water shortage due to high water abstraction and low freshwater recharge needs to develop a strategy to quantify water resources so as to exploit them rationally and maintain quality. Poor allocation and supply of water resources threaten long- term economic development with direct effect on food production.

1.7 Conceptual Framework

Safe drinking water is a basic necessity to the survival of human beings. However, the informal settlement lacks the treated water and often end up fetching water from the existing sources which are basically polluted. The residents' level of awareness of treatment methods is absent which results to incidences of water borne diseases. With basic hygiene knowledge the residents will reduce the incidences of water borne diseases with an aim of achieving quality drinking water (See figure 1.1).

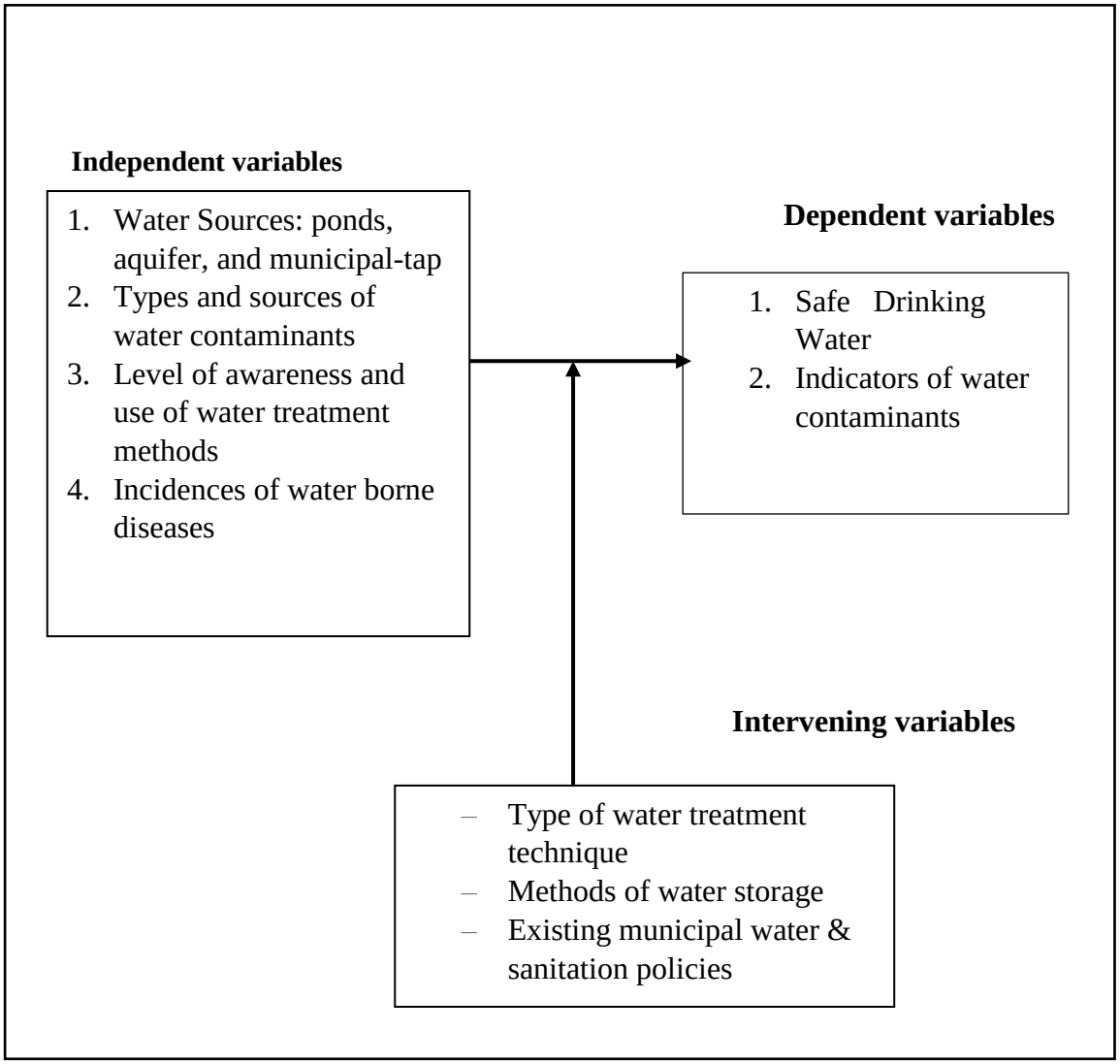

Figure1.1: Conceptual framework, adapted from (Author, 2013)

1.8 Scope of the Study

The research study only covered Gachagi informal settlement within Thika Municipality. It limited itself to domestic water sources and resident's awareness of the effects of drinking contaminated water to their general health.

1.9 Definitions of Operational Terms

Aquifer	A water reservoir trapped between impervious rocks.
Contaminants	Harmful substance or organisms found in water and food.
Degenerate	Condition becoming worse, lower in quality or more dangerous.
Degradation	Loss of economic, ecological and aesthetic values of an area as a result of human interference.
Floodplain	Flat area on the edge of river where the ground consists of soil, sand and rock left by the river when it floods.
Infections	Diseases caused by germs or bacteria.
Landfills	Method of getting rid of very large amounts of rubbish by burying it in a large deep hole.
Ravine	A very deep narrow valley with steep sides.
Respondents	In this study is a household head or an adult 18 years and above of the study area.
Slums	Areas in city where living condition and houses are in bad condition
Waterborne disease	Infection on people due to drinking infected water.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

According to the United Nations Human Settlements Program (UNEP, 2012), nine hundred and twenty-four million people lived in slums in 2001. Population growth in these settlements is much greater than in other urban areas. The estimate suggested that this figure could rise to one and a half billion by 2020 (Jones, 2016). This rapid increase in slums is expected despite "slum upgrading" efforts that have been taking place for decades, though inconsistently and with disruptions over time. The situation is particularly acute in Africa where, on average, over 70% of the urban population lives in informal settlements (Hunter, et al., 2012).

According to the Duressa et al. (2019), more than three million people die each year from water- borne disease, most of whom are young children. It is estimated that above 50% of the population in developing countries is suffering from water - related disease at one time. This makes infections from contaminated water supplies a leading cause of illness and death worldwide and helps to explain the importance of provision of safe-drinking water and hence should be such a high priority for governments and aid agencies. The majority of water borne infections is a result of feacal contamination, either from humans or animals hence, preventing sewage and agricultural effluent from entering water supplies is the key to safe drinking water (Wright et al., 2014).

There is simply not enough uncontaminated, disinfected drinking water in many areas of the globe to meet the basic needs of human consumption. Despite the fact that water covers six- tenths of the Earth's surface, clean uncontaminated drinking water is perhaps our most endangered resource (Smeenk, 2013). In some cases, water in general is very limited while other locals have an abundance of water, but it is not safe to drink or use due to chemical or biological contamination.

The World Health organization reports that in some areas of the world as much as eighty percent of all transmittable diseases are spread by water. This figure is directly or indirectly the largest single human mortality factor. However, this situation is not isolated to one geographical area but it has been spread globally. It is estimated that one quarter of the earths' population, that is, more than a billion and a half people, still do not have enough clean, safe drinking water for their daily needs (Oyunge, 2014). As an

illustration, New Delhi, India and Manila, Philippines are two of the most overpopulated cities in the World. Slum areas within these cities are up to two hundred thousand people living in one square kilometer. With so many people crammed into such a small area, it is not surprising that water supplies, adequate sanitation and healthcare are difficult to manage (Rufener et al., 2010).

The problem therefore of providing one and a half billion people living in close proximity to one another within the authority of a municipality but without the benefits of municipals services , presents a huge challenge to bringing clean water, sanitation and hygiene to the entire world (Rufener et al., 2010) .The world health Organization says that every year, more than two million people die as a result of water related diseases, making it the leading cause of disease and death around the World. Most of the victims are young children, majority of who die of illnesses caused by organisms that thrive in water sources contaminated by raw sewage (Cosgrove & Loucks, 2015).

2.2 Location of Informal Settlements

The conditions and general landscape of the slum areas makes the extension on public utilities and individuals' utilities even more difficult. Settlements are often situated on previously unused land such as steep hillsides, ravines, floodplains and even landfills. In order for municipalities to provide water and electrical service, the cities are required to establish legal tenure of who exactly has legal ownership of the property or dwelling (Misati, 2016).

2.3 Sources of Water for Domestic Uses in the Slums

Informal water service is often seen in poor slum colonies where municipal and private investment have made no in - roads at all. It is not uncommon for families in slum colonies to purchase water that has been trucked in from a borehole well that is not safe. These supplies are unregulated. The quality of water they sell is highly questionable (You, 2015).

2.4 Composition of the Mineral Content that Pollutes the Water

Water is contaminated through urine and feaces, though considered to be easily degradable, water contaminated by both animal and human waste is the most frequent

cause of transmitting bacterium and parasites into the human body. Washing clothes in polluted water is almost as bad as bathing in it as the skin comes into contact with it for most of the day, causing irritation. Also washing dishes in polluted water is almost as bad as drinking it, since food touches the plates and then enters the body (Wright et al., 2014).

Table 2. 1: Guidelines for using water with known nitrate content.

Nitrates (NO_3) parts per Million)	**Nitrate nitrogen ($NO_3 – N$) Parts per million**	**Interpretation**
0-44 ppm 88 ppm	0- 10 ppm 11- 20ppm	Drinking water; standard levels, safe for humans and livestock. Generally; safe for human adults and livestock
89- 176ppm	21- 40ppm	Generally acceptable for human adults and livestock unless high in nitrates.
177- 440 ppm	41- 100ppm	Water should not be consumed by pregnant women and human infants under 6 months old
Over 400ppm	Over 100 ppm	Water should not be consumed at all**.**

Source: Nitrates and Ground Water (Mohsin, et al., 2013) India.

2.5 Types of Water Borne Diseases

Lack of safe drinking water takes a greater human toll than war, terrorism and weapons of mass destruction combined. This is due to killer diseases related to unsafe drinking water like cholera, typhoid fever and hepatitis which are caused by bacteria and among the most common diarrhoea diseases. Other illnesses, such as dysentery are caused by parasites that live in water contaminated by the feces of sick individuals. Lakes, streams, wells, water ponds which people use for drinking water and bathing; defecating are sources of diseases as water left by natural disasters (Damo & Icka, 2013).

There are both short term and long-term measures that can be taken to prevent spread of water borne diseases by encouraging people to wash their hands as much as possible after visiting the toilets, before handling any food and utensils also boiling water before drinking. The United Nations has set a goal of cutting in half by the year 2015 the number of people without access to safe drinking water and basic sanitation. The shortage of clean drinking water has an additional impact upon the lives of many urban poor people, that is, each day is spent travelling looking for water and firewood to boil the water, the time spent comes at the expense of working for their livelihoods in order to meet other basic needs (Aryal, et al., 2012).

Table 2. 2: Organisms and associated waterborne diseases

Organisms	**Reservoir (Where they live and grow)**	**Comments**
Bacteria Aeromanas hydroophila	Free living (can live outside other animals or in standing water)	Can be associated with cellulitis (Flesh eating) gastroenteritis (stomach and intestinal problems diarrhoea) and other disease.
Campylobacter	Birds and animals	Major cause of diarrhea is processed poultry. Causes type B gastritis (stomach upset), peptic (stomach ulcers), stomach cancers
Legionella Pneumophila	Free living and associated with protozoan, cooling towers, showers, standing water.	Fatal pneumonia can be acquired by inhaling spray.
Leptospira Mycebacterium	Infected animals Infected animals and free living	Hemorrhagic (internal and external bleeding and bruising) effects Jaundice (yellow eyes and skin) Tuberculosis, Leprosy
Salmonella enteriditis	Animals intestinal tracts	Common in many waters, diarrhoea, "food poisoning"
Pseudomanas earuginosa	Free living, ponds lakes, standing water	Swimmers ear, Pink eye, skin rashes

Source: (Hansen, 2014) USA.

2.6 Policy Framework

Informal settlements in urban centers go through various phases of adhoc regulation over long periods. In this process some are connected to a formal water and sanitation network. Public policy varies by county and over time within countries but broadly speaking there are three kinds of governments in dealing with informal settlements areas and the associated problem (Ali, et al., 2013).

Common to all informal settlements is often dubious nature of land tenure which can be seen mainly in terms of land tenure often not granted because of invasion of public

and private land or construction of dwellings that fail to meet urban planning regulations (Shrestha, 2014). The procedures for granting tenure and implementation of urban development plans frequently takes decades. In Lima, for example, it took twenty years to legalize informal settlements. In Tanzania, it takes seven years to identify an area for implementation of urban planning (Muraguri, 2013).

Land tenure and ownership poses another problem. Clauses in concession or lease contracts which specifically require the extension of services to informal settlements, were generally absent from most of the contracts negotiated in 1990`s and bidders were not required to outline their strategies for improving services to low-income residents (Waggoner, 2011). Tanzania, which excluded an obligation on the part of the private operator to exposed services to pre -urban settlements, and only a small amount of funding provided separately by the donor agencies were devoted to improving connections. The same was true of societies' services contract with the government of Cote d'lvore, which excluded slums where residents obtain water from customers with house hold connections who resell water to those without taps (Seib, 2011).

2.7 Knowledge Gaps

Various challenges arise from low investment and maintenances of existing water infrastructure as a factor of low access to quality water demand and high network losses. Literature review gave a general conclusion about the growing water demand and unsustainable use of the natural resources without specifying the level of household water demand and the actual population still living without access to safe drinking water supply and how to manage the unsustainable use of the finite resource. What is not clear in the literature is whether the deteriorating access of improved water is the result of physical water shortage, infrastructural constraints, mismanagement or inadequate human and institutional capabilities to tackle the situation. With a view to contributing to such knowledge this study aims to analyze and determined the magnitude of household access to improved water demand and distribution coverage, factors that contribute to deteriorating access to pipe water demand and the effectiveness of the current water use management strategies. But households' level of awareness of the existing health risks associated with the use of contaminated water, the preventive measures to improve the quality of drinking water and the willingness to pay for improved water is beyond the scope of this study.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methodology to be used in the study that include the study area, the research design, target population of the study, sampling procedures, sample size, instrumentation, data collection procedures and data analysis procedures.

3.2 Area of the Study

Thika Municipality is administratively located in Kiambu County of Central Kenya. Kiambu County is a county in the former Central Province of Kenya covering 946km². Its capital is Kiambu town and its largest town is Thika. The county is adjacent to the northern border of Nairobi County and has a population of 1,623,282 lying 1° 10' 0" S, 36° 50' 0" E, and about 1,720 m above sea level. The geographical co-ordinates for Thika Town are 1° 01' 59.74" S, (Latitudinal extent) and 37° 04' 9.59" E, (Longitudinal extent). It lies at a height of approximately 1700 m'. It is to the eastern lowlands of Nyandarua ranges and facing adjacent Athi-Kapiti plateau. Gachagi is 50 km from Nairobi City. Gachagi informal settlement is to the Eastern outskirts of Thika Town. The study was conducted within Gachagi informal settlement in Thika Municipality. Gachagi informal settlement was purposively studied as there was no other studies that had been carried out about the status of drinking water. (figure 3.1).

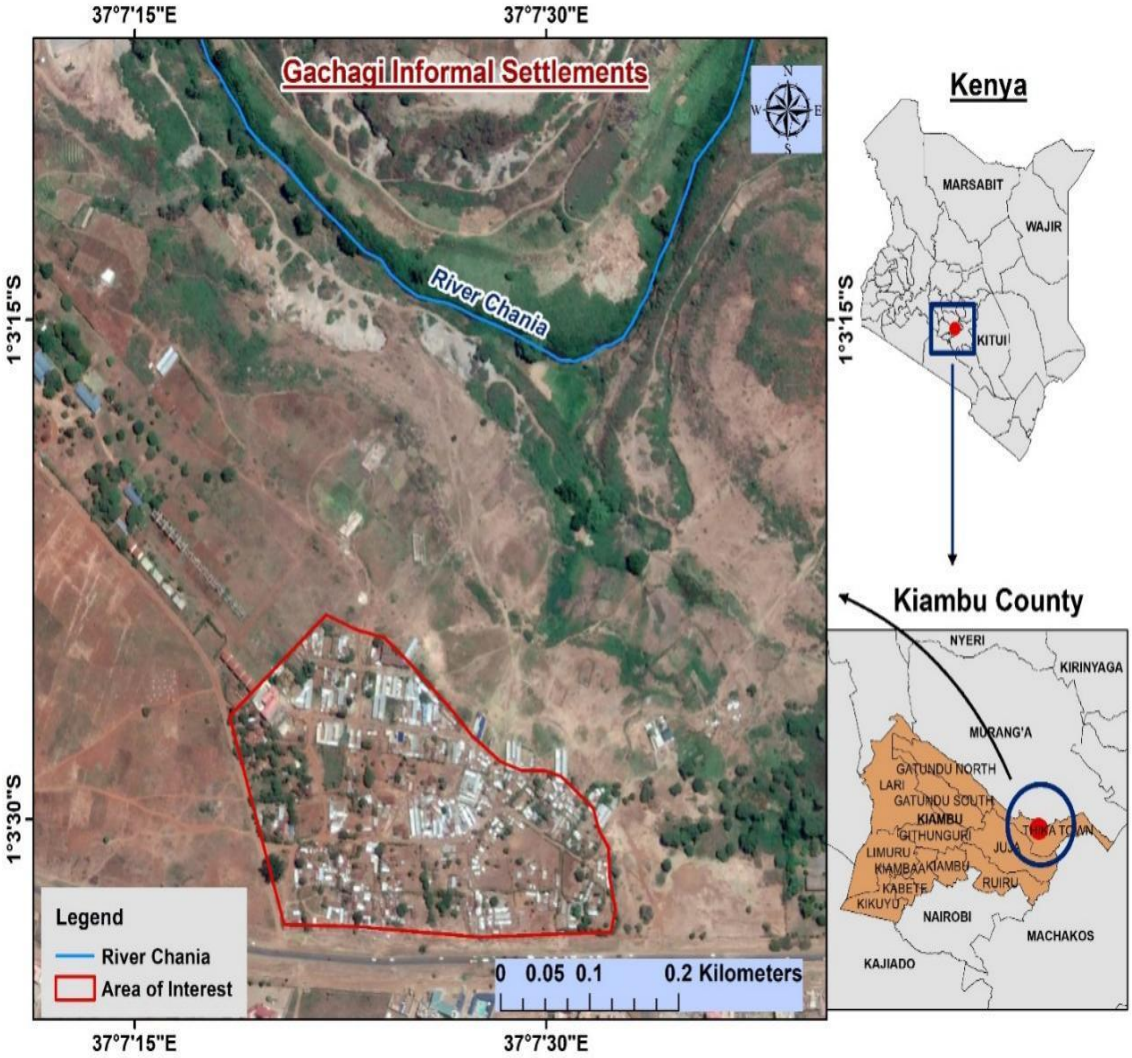

Figure 3. 1: Map of the study area. Data Kenyatta University GIS Lab

3.3 Study Design

The study adopted descriptive and experimental design. Under quantitative approach, the researcher employed analytical cross-sectional design. The design was selected for this study due to its ability to ensure minimization of bias and maximization of the reliability of evidence collected.

3.4 Target Population

The study targeted a population of six hundred households at Gachagi informal settlement (Kiambu County Report, 201 4). Adult respondents were involved in answering the questions from an interview schedule. Questionnaires were given out to literate respondents. Interviews were conducted among the interviewees who were adults, who included household heads, the area chief, slum elders, local non-governmental organizations and Thika Sub-County Health Officers and Environmental Officer.

3.5 Sample Size

The target population was six hundred adult individuals out of which a sample of one hundred and forty-eight were selected. According to Mugenda & Mugenda (2003), big samples are always the best despite resources and time constraints. In determining the sample size, the Mane *et al.*, (2007) formula was applied.

$$n = \frac{NZ^2pq}{e^2(N-1) + Z^2pq}$$

Where e = 0.02 (since the estimate should be within 2% true value)

z = 2.005 (as per table of area under normal curve for the given confidence level of 95.5 %.)

p = may be estimated to be 0.02

$$n = \frac{600 * 2.005^2 * 0.02 * (1 - 0.02)}{0.02^2(600 - 1) + 2.005^2 * 0.02(1 - 0.02)}$$

$\therefore n =$ 148

3.6 Sampling Procedure

A sample should be large enough to be representative of the larger population (Waggoner, 2011). The study adopted a multistage sampling technique, convenience sampling was used to select one County in Kenya, with Kiambu County selected. Then a cluster random sampling to create the sample frame among the 12 sub counties, to select one sub counties (Thika Sub County) due to time and resources. Using a list of informal settlements available from Thika Sub County, a stratified random sampling was used to select one informal settlement (Gachagi informal settlement). Stratified random sampling is defined as a method of sampling involving grouping of a population into smaller categories known as strata. Strata formed on the basis of the members shared charateristics or attributes. Systematic sampling technique was used to select the households from the larger population that will be selected according to a random starting point and a fixed periodic interval (k^{th} number) this sampling method gave each household an equal opportunity to be selected for the interview. Estimated total population is 600 and sample size 148 therefore k=4. The first household was picked by simple random sampling and the other households picked by systematic sampling at intervals of 4. The simple random sampling picked household number 2. Therefore, systematic sample consisted of units with serial number i.e., 2, 6, 10, 14, 18…..... Household head from the selected households or an occupant aged eighteen years and above were interviewed. Water samples were taken from water points that were selected randomly; about twenty samples for laboratory tests. Water samples were collected from Municipal taps, two shallow wells, two water ponds, River Chania and two boreholes.

Key informant interviews (KII) for the area chief, slum elders, local non- governmental organizations and Thika Sub-County Health Officers and Environmental Officer were conducted. It was determined using the data saturation method. Saturation is data satisfaction which involved adding more participants to the study that does not result in additional perspectives or information. It is when the researcher reaches a point where no new information is obtained from further data. Saturation point determines the sample size in qualitative research as it indicates that adequate data has been collected for a detailed analysis.

3.7 Instruments for the Study

The researcher used structured questionnaires, some of which contained closed and others open ended questions. Pre-testing the research tools like questionnaires for a few people, that is, thirty was conducted before undertaking the project at Gachororo slums. The study sample analysis in the laboratory tests and interview schedules as research instruments.

3.8 Data Collection Procedures

3.8.1 Interviewer administered questionnaire

This is the research tool that used an interview schedule; the questions were used for all respondents interviewed. Study respondents were approached from the selected household to participate in the study. Necessary information's that are study related were provided such as informed consent, objectives, accompanied by a structured, pre-tested administered questionnaire to collect data were provided and interview carried out at in a selected place. The questionnaire comprised close-ended and multiple-choice questions. The principal investigator and research assistants read out the question as it is from the questionnaire to the respondents and then document the findings.

3.8.2 Direct Observation

This included observing and recording the sources of water and precautionary measures taken in each household to ensure the safety of domestic water.

3.8.3 Water Analysis

Water from River Chania were collected midstream at a depth of about 20cm using vertical and horizontal messenger activated samplers (Kemmerer water samplers). Temperature and pH were measured insitu, using a temperature probe and a portable pH meter, respectively. Electrical conductivity (EC) and total dissolved solids (TDS) were determined on site using total dissolved solid (TDS) and conductivity meter Jenway model 4076. Samples for bacteriological analysis were collected into sterilized 1-litre plastic bottles while ensuring no air bubbles were present, stored in an icebox at 4°C and transported to the Kenyatta University Microbiology laboratory for analysis within the stipulated time of 6 hours for testing of water contaminants, which was done

at noon. Multiple tube fermentation technique was used to enumerate contaminants in water. The principle of replication was used; this involves collecting samples and repeating the experiment several times, in order to increase the precision of the study.

During the water analysis, multiple tube fermentation was used to enumerate coliform bacteria. The coliform group consists of several genera of bacteria belonging to the family of entero-bacteria case. According to the fermentation technique used, this group is defined as all facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas and formation within 48 hours at 35 degrees Celsius. Multiple tubes were used in the fermentation technique, results of the examination of replica tubes and dilutions were reported in terms of the Most Probable Number (MPN) of organisms' present. This number, based on certain probability formulas, is an estimate of the mean density of coliforms in the sample. Coliform density, together with other information obtained by sanitary survey provides the best water treatment effectiveness and sanitary quality of source water. The precision of each test depends on the number of tubes used. The most satisfactory information is obtained when the largest sample inoculums examined shows gas in some or all of the tubes and the smallest sample inoculums shows no gas in all or majority of the tubes .Testing of ecoli was done using World Health Organisation procedure.

3.9 Data Analysis

Basing on the mixed method approach, data was analyzed using both descriptive and inferential statistics. Since the variables fell within the three scales of measurement; nominal, ordinal and ratio scale, non-parametric statistical tests were employed. Data from questionnaires and interview schedules were coded so that responses could be grouped into distinct categories of attributes so as to permit the use of SPSS software to yield percentages from frequency table and permit terms of associations that is Spearman's Rank Order correlation and Chi-Square. Data was presented in charts, graphs, frequency tables and pie-charts. Relevant interpretation, discussions and recommendations were drawn from the analysis.

3.10 Logistical and Ethical Consideration

To conduct this study, approvals were given from Kenyatta University Graduate School, permit from National Committee of Science, Technology and Innovation and ethical approval from Kenyatta University Ethical Committee (KU-ERC) also from relevant authorities at Kiambu County. Informed consent was obtained from the respondents. The right to participate in the study or not rested with the respondents and this was respected at all times during the study. Respondents were informed that was their right to choose whether to participate in the study or not and even withdraw from the study at any time, which would not affect the care they would receive. No inducements or rewards were given to participants to join the study. Confidentiality and anonymity were maintained at all times. No identifying data was recorded and all information given were used strictly for research purposes only and data collected was stored, analyzed and reported in formats that would not allow identification of the individual participant. There were no invasive procedures carried out on the participants, so no physical risks were encountered. Results of the study was communicated to Kenyatta University and Kiambu County.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results and discussion of findings obtained from research done at Gachagi informal settlement on safety of drinking water. The results indicate that the residents of this informal settlement have various sources of domestic water whose safety is questionable. The findings also identified various opportunities that exist in Gachagi informal settlement for improvement of current situation. Where appropriate, graphs and tables have been used to present the findings.

4.2 Questionnaire Response Rate

The study targeted 148 participants, out of whom, 140 responded to the questionnaires contributing to an aggregate response rate of 94.6% (as illustrated on Table 4.1). This response rate was sufficient and representative and conforms to Mugenda and Mugenda (2003) stipulation that a response rate of 50% is adequate for analysis and reporting, a rate of 60% is good while a response rate of 70% and over is excellent.

Table 4. 1: Questionnaire response rate

Response	**Frequency (n)**	**Percentage (%)**
Completed questionnaires	140	94.6
Incomplete questionnaires	8	4.7
Total	**148**	**100.0**

4.3 Demographic Characteristics of the Respondents

4.3.1 Age

The respondents age ranged from 18 years to 68 years, the mean age was 41 years ± 3.40. The findings showed that 35% (n=49) were between 35-44 years, 23.6% (n=33) between 45-54 years, 12.9% (n=18) were 55 years and above and 9.3% (n=13) were below 25 years.

Table 4. 2: Distribution of respondents by age

Characteristics	Frequency(n)	Percentage (%)
Age		
Less than 25 years	13	9.3
25-34 years	27	19.3
35-44 years	49	35.0
45-54 years	33	23.6
≥ 55 years	18	12.9
Total	**140**	**100**

4.3.2 Gender

The males were 71.4% (n= 100) while females were 28.6%(n=40) as shown in Table 4.3

Table 4. 3: Distribution of respondents by gender

Characteristics	Frequency(n)	Percentage (%)
Gender		
Male	100	71.4
Female	40	28.6
Total	**140**	**100**

4.3.3 Level of Education

Of all respondents 45% (n=63) had primary level of education

Table 4. 4: Distribution of respondents by level of education

Characteristics	Frequency(n)	Percentage (%)
Education Level		
No formal education	22	15.7
Primary	63	45.0
Secondary	42	30.0
Tertiary	13	9.3
Total	**140**	**100**

4.3.4 Occupation of Respondents

At the study area, 39.3% (n=55) of respondents were unemployed while 24.3% (n=34) were employed.

Table 4. 5: Distribution of respondents by occupation

Characteristics	Frequency (n)	Percentage (%)
Occupation of respondents		
Casual labourer	39	27.9
Self-employed	34	24.3
Student	12	8.6
Unemployed	55	39.3
Total	**140**	**100**

4.3.5 Length of Stay at Gachagi Informal Settlement

Most of the respondents 27.9% (n=39) had lived in Gachagi informal settlement for 5-9 years, 25.0% (n=35) had lived for 15-19 years while 4.3% (n=6) had lived for less than one year. This implied that cumulatively, 96% of the study respondents had lived in Gachagi informal settlement for more than 5 years. This also implied that they had lived in the slum for long enough to appreciate the way of life in the slum especially on matters touching on the safety of drinking water.

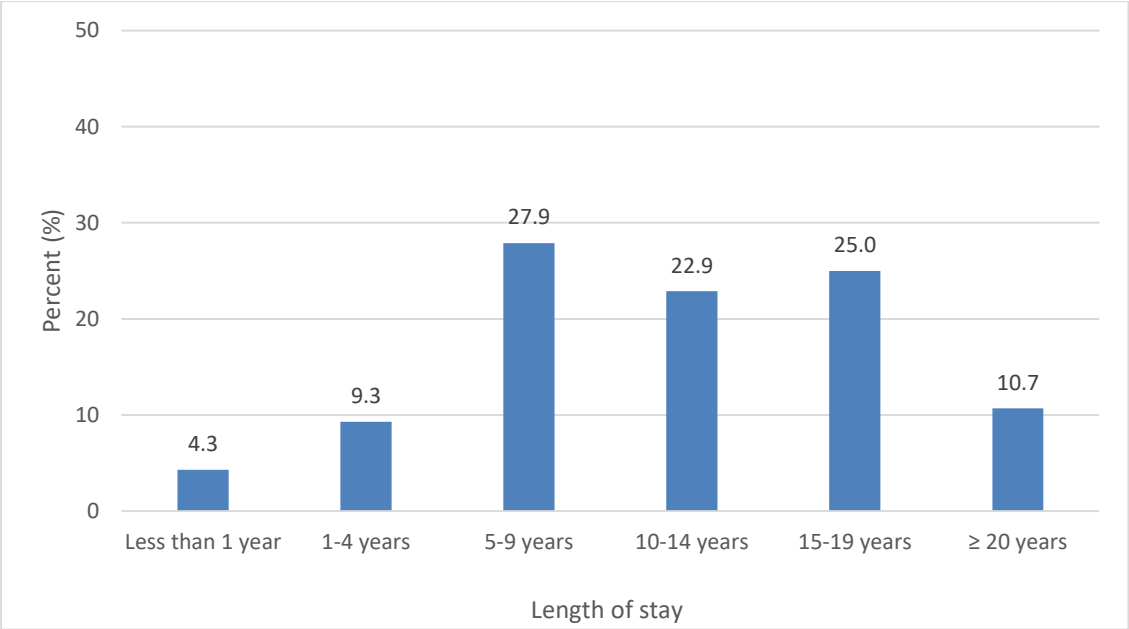

Figure 4. 1: Length of stay at Gachagi informal settlement

4.4 Domestic Water used in Gachagi Informal Settlement

4.4.1 Sources of water in Gachagi informal settlement

Objective one of the study was to find out major sources of domestic water used by residents of Gachagi informal settlement. Consequently, several questions were asked in order to achieve this objective:

Figure 4.2 shows that the main sources of water were municipal-taps 42.1% (n=59), shallow wells 25.0% (n=35), water-ponds 23.6% (n=33), River Chania 5.0% (n=7), boreholes 2.1% (n=3) and rain water 2.1% (n=3).

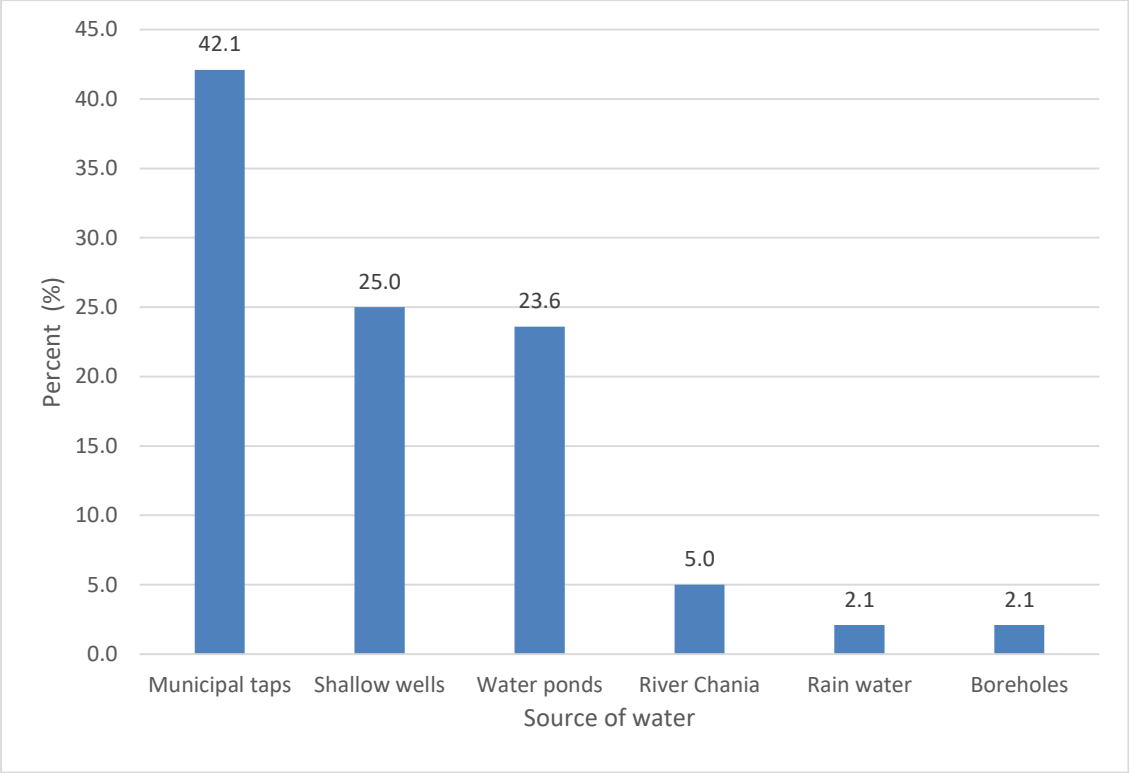

Figure 4. 2: Sources of water in Gachagi informal settlement

These findings were in agreement with Attari, et al., (2017) who assert that it is not uncommon for families in slum colonies to purchase water that has been trucked in from a borehole well that is not safe. These supplies are unregulated. The quality of water they sell is highly questionable.

4.4.2 Transportation of Water

The study also sought to find out how water was transported from the source to the point of use. The findings were as shown on Figure 4.3.

Most of respondents 60.0% (n=84) transported water using open buckets with no lids while 40.0% (n=56) of the respondents transported water using jerricans with lids.

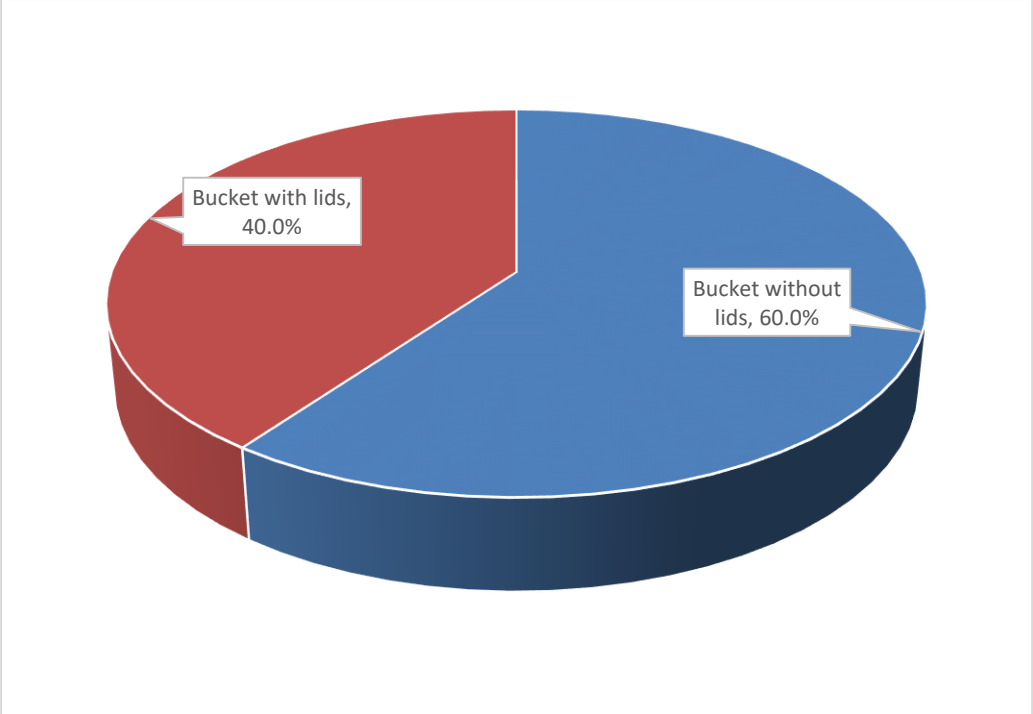

Figure 4. 3: Transportation of water

4.4.3 Socio-Demographic Characteristics with Transportation of Water

Most of respondents aged between 45-54 years 72.7% (n=24), male 64.0% (n=64) with no formal education 68.2% (n=15) used bucket without lids to transport water. Respondents between 25-34 years 51.9% (n=14), female 50.0% (n=20), with tertiary education 61.5% (n=8) and 50.0% (n=6) of student used bucket with lid for water transportation. Age (p=0.011), gender (p=0.020) and level of education (p=0.046) of respondents had significant association with transportation of water.

Table 4. 6: Socio-demographic characteristics with transportation of water

	Bucket without lid	Bucket with lid	Total		Statistic
			n	%	
Age group					
Less than 25 years	8	5	13	9.3	x^2=9.596
25-34 years	13	14	27	19.3	(4)
35-44 years	29	20	49	35.0	p=0.011
45-54 years	24	9	33	23.6	
≥ 55 years	10	8	18	12.9	
Gender					x^2=9.792
Male	64	36	100	71.4	(1)
Female	20	20	40	28.6	p=0.020
Level of education					
No formal education	15	7	22	15.7	x^2=6.141 (3)
Primary	42	21	63	45.0	p=0.046
Secondary	22	20	42	30.0	
Tertiary	5	8	13	9.3	
Occupation					
Casual labourer	27	12	39	27.9	x^2=6.433 (3) p=0.092
Self-employed	18	16	34	24.3	
Student	6	6	12	8.6	
Unemployed	33	22	55	39.3	

4.5 Types and Sources of Water Contaminants

4.5.1 Perception of drinking water

Perception of water used for drinking at Gachagi informal settlement is contaminated increased with age and 75.0% (n=30) of females and 84.6% (n=11) of respondents with tertiary education perceived the water is contaminated. However, all variables were significantly associated with perception of water being contaminated.

Table 4. 7: Respondent's perception of drinking water

	Safe	Contaminated	Total		Statistics
			n	%	
Age group					
Less than 25 years	6	7	13	9.3	
25-34 years	10	17	27	19.3	x^2=6.345 (4)
35-44 years	18	31	49	35.0	p=0.021
45-54 years	14	19	33	23.6	
≥ 55 years	6	12	18	12.9	
Gender					
Male	44	56	100	71.4	x^2=4.170 (1)
Female	10	30	40	28.6	p=0.027
Level of education					
No formal education	11	11	22	15.7	
Primary	28	35	63	45.0	x^2=3.376 (3)
Secondary	13	29	42	30.0	p=0.031
Tertiary	2	11	13	9.3	
Occupation					
Casual labourer	17	22	39	27.9	
Self-employed	18	16	34	24.3	x^2=4.192 (3)
Student	4	8	12	8.6	p=0.039
Unemployed	15	40	55	39.3	

4.5.2 Source of Contamination

The study discovered that the main sources of contamination were; animals 69.8% (n=60) especially dogs, goats, sheep and cows drinking from the source adults washing clothes 60.5% (n=52). Young children were also being bathed 66.3% (n=57) at water source. Children defecating on the source 62.8% (n=54) and on ground without proper disposal was also reported. This implied that when it rained the surface run-off carried the feaces and deposits to the water sources. Open pit latrines and dumping of the garbage 39.5% (n=34) all over the compound also was source of contamination of water sources.

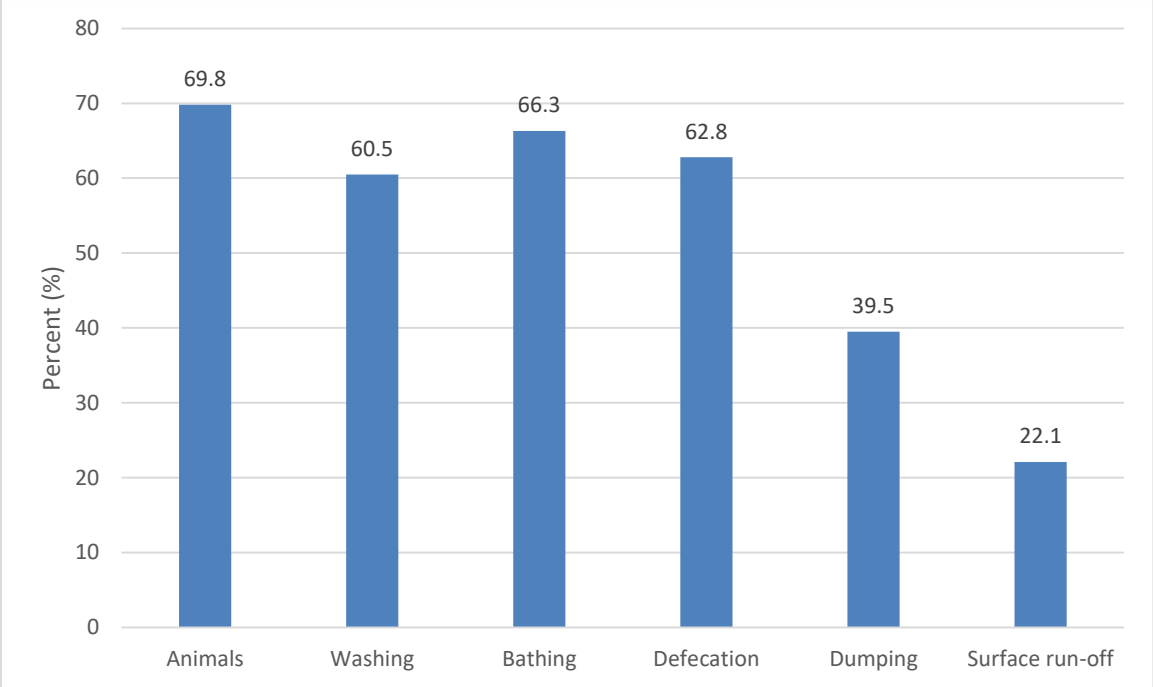

Figure 4. 4: Source of contamination

These findings agree with Wright et al., *(*2014) who argued that water is contaminated through urine and feaces, though considered to be easily degradable, water contaminated by both animal and human waste is the most frequent cause of transmitting bacterium and parasites into the human body. Washing clothes in polluted water is almost as bad as bathing in it as the skin comes into contact with it for most of the day, causing irritation. Also washing dishes in polluted water is almost as bad as drinking it, since food touches the plates and then enters the body.

4.5.3 Comparison of Various Sources and Types of Pollutant

Most of the contaminated water were polluted through defecation 80.7% (n=71), surface ran-off 70.9% (n=22), washing 66.9% (n=57) and dumping 65.6% (n=36) and the source of pollutants had significant association with water contamination.

Table 4. 8: Comparison of Various Sources and Types of Pollutant

		Safe	Contaminated	Total		Statistics
				n	%	
Animals	Yes	34(34.8%)	64(65.2%)	98	69.8	x^2=7.310 (1)
	No	20(47.6%)	22(52.4%)	42	30.0	p=0.008
Washing	Yes	28(33.1%)	57(66.9%)	85	60.5	x^2=5.826 (1)
	No	26(47.3%)	29(52.7%)	55	39.3	p=0.023
Bathing	Yes	33(35.6%)	60(64.4%)	93	66.3	x^2=6.900 (1)
	No	21(44.7%)	26(55.3%)	47	33.6	p=0.017
Defecation	Yes	17(19.3%)	71(80.7%)	88	62.8	x^2=12.014 (1)
	No	37(71.2%)	15(28.8%)	52	37.1	p=0.003
Dumping	Yes	19(34.4%)	36(65.6%)	55	39.5	x^2=16.754 (1)
	No	35(41.2%)	50(58.8%)	85	60.7	p=0.0001
Surface run-off	Yes	9(29.1%)	22(70.9%)	31	22.1	x^2=4.183 (1)
	No	45(41.3%)	64(58.7%)	109	77.9	p=0.019

4.5.4 Use of latrines by adults and children

Most 37.0% (n=37) of males used the public latrine, while 35.0% (n=14) of female respondents used the same public latrine. At least 8.0% (n=8) and 7.5% (n=3) of males and females' respondents did not have latrines hence used nearby bushes above the water sources respectively.

Table 4. 9: Use of latrines by respondents

		Defecation places			
		Family latrine	Public latrine	Neighbor latrine	Bushes
Adults	Male	29	37	26	8
	Female	9	14	14	3
All category		38	51	40	11
Proportional %		27.1	36.4	28.6	7.9

Key informants said the County Environment Department has teamed up with other stakeholders and private sectors in achieving a safe and healthy environment through building enough latrines in the slum.

"When learning about the environment's declining health it is easy to feel discouraged, but what keeps us fighting for a healthy world is the future of our children. They should not have to inherit our environmental problems and in order to keep their future bright, spreading awareness and building latrines in this locality is imperative, at least the department of environment is working non-stop to ensure that" (KII 1).

4.5.5 Water Analysis

World health organization standards recommend drinking water to have zero presence of coliforms bacteria. However, all water samples tested indicated presence of coliforms bacteria. Fecal Coliforms bacteria was present in all the tested water indicating high risk as shown in table 4.9. Escherichia coli (E. coli) bacteria was also found to be present except in municipal tap water.

Table 4. 10: Water analysis

	Turbidity (NTU)	Fecal Coliform (Cfu/100ml)	Fecal E. Coli test	Total Coliform (Cfu/100ml)
Municipal taps	3.77	4	0.0	13
Shallow wells	33.9	17	2.5	56
Water ponds	47.6	29	3.5	113
River Chania	62.3	79	3.0	189
Boreholes	54.3	71	4.0	121
WHO recommendation	**<5**	**0**	**0**	**0**
Kenya recommendation	**<5**	**0**	**0**	**0**

4.6 Methods of Water Treatment

4.6.1 Awareness and use of various methods of water treatment

The respondents were required to indicate their awareness and use of various methods of water treatment and their responses were as shown on Table 4.11. Majority 65.0% (n=91) of respondents were aware of water treatment methods while 35.0% (n=49) were not. Those who were aware, indicated boiling of water 50.5% (n=46), chlorination 20.9% (n=19) and filtration with a piece of cloth 17.6% (n=16) as the method of water treatment used.

Table 4. 11: Awareness and use of various methods of water treatment

Characteristics		**Frequency(n)**	**Percentage (%)**
Aware of drinking water treatment	Yes	91	65.0
	No	49	35.0
	Total	**140**	**100.0**
Methods of water treatment	Boiling	46	50.5
	Leave to settle	10	11.0
	Filter with a piece of cloth	16	17.6
	Chlorination	19	20.9
	Total	**91**	**100.0**

4.6.2 Socio-Demographic Characteristics with Treated Drinking Water

Socio-demographic characteristics and their association with treatment of drinking water was investigated. Variables analyzed were age, gender, level of education and occupation. Respondents who had a formal education had higher rates of treating drinking water and this was significantly associated with treatment of drinking water (x^2=8.413; p=0.038). All the other variables had no association with treatment of drinking water.

Table 4. 12: Socio-demographic characteristics with treated drinking treatment

	Treated drinking water		Total		Statistic
	Yes	No	n	%	
Age group					x^2=5.348 (4)
Less than 25 years	10	3	13	9.3	p=0.148
25-34 years	19	8	27	19.3	
35-44 years	30	19	49	35.0	
45-54 years	24	9	33	23.6	
≥ 55 years	8	10	18	12.9	
Gender					x^2=3.460 (1)
Male	60	40	100	71.4	p=0.063
Female	31	9	40	28.6	
Level of education					x^2=8.413 (4)
No formal education	9	13	22	15.7	p=0.038
Primary	32	31	63	45.0	
Secondary	37	5	42	30.0	
Tertiary	8	5	13	9.3	
Occupation					x^2=1.119 (3)
Casual labourer	21	18	39	27.9	p=0.571
Self-employed	28	6	34	24.3	
Student	10	2	12	8.6	
Unemployed	32	23	55	39.3	

4.6.3 Environment Cleaning

In terms of a clean environment the respondents applied the method of burning waste 65.7% (n=92), clearing the bushes 37.9% (n=53) however none of the respondents used lids to cover their pit latrines and did not see the need of planting trees within their compounds. Majority of respondents 81.4% (n=114) said they had never had an environmental awareness program in Gachagi informal settlement.

Table 4. 13: Environment cleaning

Characteristics		Frequency (n)	Percentage (%)
Cleaning environment	Burning waste	92	65.7
	Clearing bushes	53	37.9
	Total	**145**	**100.0**
Environment awareness program	Yes	26	18.6
	No	114	81.4
	Total	**140**	**100.0**

Key informants narrated that there are three different pillars economic, social and environmental that are based in sustainable development (SD). In some situations, they offer health education to achieve the desired level of SD balance between all these three elements, are very important as they should be integrated. Alternatively, they have a cordial relationship with community health workers, they educate them and they do the same to community members on how to keep environment clean. Both of these situations cause increased knowledge on cleanliness. But they don't achieve more in Gachagi area, the environment cleanliness cases in Gachagi area are almost a monthly thing, but community participation is not seen at all, note that majority live below a dollar a day, they don't have a permanent job, they don't receive a monthly salary, so in case they don't walk out to find a daily bread, they won't feed that night. So, they don't see the need of participating in health education and environmental cleanliness, note that the success of such initiatives, however, depends mostly on people. Their personal approaches and opinions as well as their understanding of problems are vital to introduce positive changes. Authorities have their tools to enforce the desired behaviors but the community is reluctant in accepting the change.

4.7 Link between Level of Awareness and Water Contaminants

4.7.1 Level of Awareness

The study sought to find out the level of awareness of the link between the water contaminants and incidences of water borne diseases in Gachagi informal settlement. The results showed that Gachagi residents recorded an average significant level of awareness of water-borne diseases associated with unsafe drinking water. By implication, these findings showed that majority of the residents were unaware of the dangers posed by unsafe drinking water and would be supportive of any policy geared towards access to safe drinking water in fulfilment of sustainable development goals and to ensure environmental sustainability

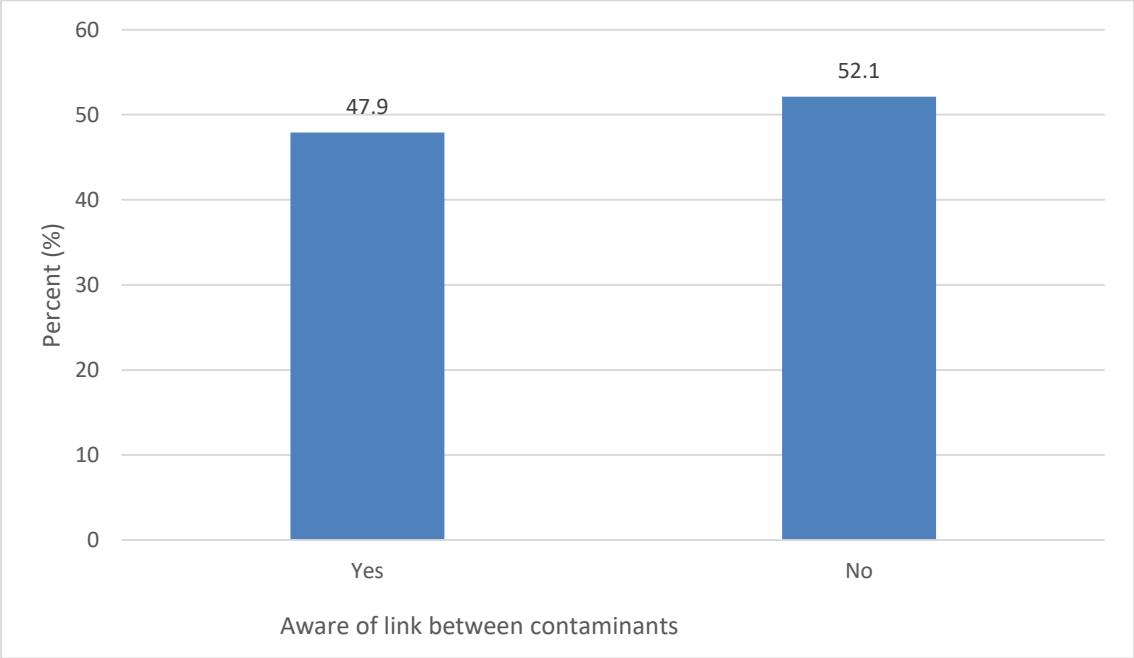

Figure 4. 5: Level of awareness of link between contaminants

All the key informants agreed that there are inadequate health care workers to offer services to community in slums. Availability of resources to carry out extensive sustainable environment is a problem in most cases. Scarce resources were commonly cited by environment officer and public officer as structural barriers. “Many of us, who have necessary skills and information lack necessary amenities to go around the slum to offer necessary information and thus travels to over 5 kilometers on foot. No one to

assist you on the other corner of slum, you don't have enough IEC materials to cover at least half of the slum, you find most of information reaches to the few". "…...but in order to really engage the society in the realization of the common goal, the instruments that could change the internal attitudes are needed, this is what is lacking in this scenario".

4.7.2 Socio-Demographic with Level of Awareness

Among socio-demographic factors associated with awareness of the link between contaminants and waterborne diseases, according to the study were age (x^2=8.321 (4) p=0.024) as well as gender (p=0.014) level of education (p=0.019) and occupation (p=0.042) as shown in table 4.14. Residents with low level of education scooped drinking water from ponds, aquifer and the river using any container. The same container was used for drinking water and for other purposes. Residents who had not received formal education and did not have latrines had their children defecating in the open. In terms of socio-economic environment households with low level of income had their members defecating in the open and the waste was disposed by throwing in the bush or left in the open, which confirms socio-economic environment also had an influence on the safety of drinking water.

Table 4. 14: Socio-demographic with level of awareness

	Awareness of link of contaminants		Total		Statistic
	Yes	No	n	%	
Age group					
Less than 25 years	5	8	13	9.3	
25-34 years	10	17	27	19.3	x^2=8.321 (4)
35-44 years	22	27	49	35.0	p=0.024
45-54 years	24	9	33	23.6	
≥ 55 years	6	12	18	12.9	
Gender					
Male	40	60	100	71.4	x^2=5.967 (2)
Female	27	13	40	28.6	p=0.014
Level of education					
No formal education	5	17	22	15.7	
Primary	29	34	63	45.0	x^2=6.419 (3)
Secondary	25	17	42	30.0	p=0.019
Tertiary	8	5	13	9.3	
Occupation					
Casual labourer	19	20	39	27.9	
Self-employed	18	16	34	24.3	x^2=5.133 (3)
Student	7	5	12	8.6	p=0.042
Unemployed	23	32	55	39.3	

4.9 Hypothesis Testing

To determine the relationship between water source and level of water contamination, the researcher tested the study hypothesis using a Chi-Square (x^2) model at 95% confidence level. The results were as shown on table 4.15.

Table 4. 15 Relationship between water source and level of water contamination

Hypothesis	Chi-sq.	Sig. Value	Result	Decision
H_1	0.341	0.05	0.341>0.05	H_1: failed to reject
H_2	0.248	0.05	0.648>0.05	H_2: failed to reject

From the study findings on table 4.13, at 95% confidence level, both Hypotheses (H_1 and H_2) yielded Pearson's P-value <0.05, hence, the study failed to reject both Alternate hypotheses (H_1 and H_2). Therefore, there was a significant relationship between water source and level of water contamination, and the community in Gachagi was aware of the various methods of water treatment.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of findings, conclusion and recommendations of the study in line with the objective of the study. The research sought to explore the relationship between the source of water and level of contamination towards safe drinking water in slums in slums, a case study of Gachagi informal settlement.

5.2 Summary

5.2.1 Sources of Drinking Water

The study established that the common sources of drinking water were municipal-taps, water-ponds, shallow wells, River Chania, boreholes and rain water 2%.

5.2.2 Types and Sources of Water Contaminants

The study discovered that the main sources of contamination were; animals especially dogs, goats, sheep and cows drinking from the aquifer, and adults washing clothes in the aquifer. Young children were also being bathed in the ponds. Also, jerricans and buckets which were used to fetch water were without lids. Failure to wash hands after visiting toilets then handling food during preparation before cooking was also prevalent. Cases of children defecating on the ground without proper disposal was also reported. Open pit latrines and dumping of the garbage all over the compound meant there were a lot of flies.

In the use of latrines, 37(37.0%) of males used the public latrine, while 14(35.0%) of female respondents used the same public latrine. At least 8(8.0%) and 3(7.5%) of males and females' respondents did not have latrines hence used nearby bushes above the water sources respectively. Children's waste was swept with rubbish while 32% was disposed in the bushes. Flies were a major problem and present in 88.7% of the households a complementary in the diarrhoea chain especially in the transfer of pathogens from feaces to food. 72.8% of the compounds were not swept.

Human feaces were noted in 37(26.7%) compounds indicating poor disposal of human waste and also occurrence of flies in the compound. Animal feaces were observed in 82(58.5%) of compounds. Only 16.5% washed hands after visiting latrines and among these only 5% used soap to clean their hands. From the water analysis results, the drinking water in Gachagi informal settlement contained coliform bacteria.

5.2.3 Awareness and Use of Various Methods of Water Treatment

Majority of respondents were aware of water treatment methods and most of the respondents boiled drinking water while about a quarter used water-tabs. However, among those who reported that they used water tabs, majority (62%) reported that they only used the water from tabs when provided by the public health officer in-charge of Gachagi informal settlement. In terms keeping the environment clean the respondents applied the method of burning solid waste and clearing the bushes however none of the respondents used lids to cover their pit latrine, some respondents and did not see the need of planting trees within their compounds because the plots were small and not privately owned. Majority of Gachagi informal settlement respondents had never had an environmental awareness program.

Gachagi residents recorded an average significant level of awareness of water-borne diseases associated with unsafe drinking water. Comparing socio-demographic characteristics with awareness of water-borne diseases, age, gender, education level and occupation were found to be statistically significant associated with occurrence of water-borne diseases.

There was a significant relationship between water source and level of water contamination, and the community in Gachagi was aware of the various methods of water treatment.

5.3 Conclusion

Main sources of water were municipal taps, shallow wells, water ponds and river. Most of respondents 84(60.0%) transported water using open buckets with no lids.

Human activity were main contaminants of water sources such as washing, bathing, rearing animals and there was open defecation in the study area. When it rained the surface, run-off carried the feaces and deposits to the water sources thus the sources of drinking among Gachagi residents were not completely safe. This implies that the drinking water sources were possibly contaminated owing to the various predisposing factors mentioned that were observed at the water sources.

Slightly more than half of respondents were aware of water treatment methods. Respondents who had a formal education had higher rates of treating drinking water and this was significantly associated with treatment of drinking water. This implies that lack of knowledge of importance of water treatment was significant.

Most of respondents had suffered waterborne diseases such as diarrhea and typhoid, this implies that there is an indicator of poor hygienic practices among Gachagi residents. Gachagi residents recorded an average significant level of awareness of water-borne diseases associated with unsafe drinking water. By implication, these findings showed that majority of the residents were unaware of the dangers posed by unsafe drinking water and would be supportive of any policy geared towards access to safe drinking water in fulfilment of millennium development goals and to ensure environmental sustainability.

The study concludes that, there was a significant relationship between water source and level of water contamination, and the community in Gachagi was aware of the various methods of water treatment.

5.4 Recommendations

Based on the research findings, the study makes the following recommendations:

i). Water projects should be up-scaled in slums. From the study it has been established that water in slums is not safe for drinking, households must be encouraged and supported to effectively treat their stored water by adopting efficient and cost-effective methods, before using.

ii). More frequent monitoring is needed to investigate specific contributing sources of pollution to water sources and household stored water. In order to achieve universal drinking water access for all by 2030, people must take ownership of their water sources and how they store water at the household level.

iii). The community's level of awareness on the link between source of water and possible contamination should be enhanced by county health team, community health workers and non-governmental organizations in order to minimize the risk of the people contracting water-borne diseases due to ignorance.

5.5 Suggested Areas for Further Research

i). Since this study explored the relationship between the source of water and level of contamination towards safe drinking water in slums, a case study of Gachagi informal settlement, the study recommends that similar studies should be done on other slums in Kenya for comparison purposes and to allow for generalization of the findings. The researcher also suggests that a study should be done on the challenges that hinder provision of clean water in the slums in Kenya.

ii). A comparative study of challenges that hinder provision of clean water in the Kenya's slums

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APPENDICES

Appendix i: Questionnaire

Dear respondent,

I am Ms. **RUTH WANGARI MWANGI a post graduate student at Kenyatta, University School of Environmental Studies.** I am undertaking a research on "Safety of drinking water in Gachagi informal settlement, Thika Sub-County, Kiambu County, Kenya". Kindly assist by filling in the questionnaire to the best of your ability.

Your response will be purely for academic and you are assured of utmost confidentiality. Your identity will be treated as private and confidential.

This will take few minutes 10 to 15.

Date: .....

Interviewer's name: .....

Checked and verified by: .....

Date: .....

SECTION A: Background Information

1. Name of the household head.....
2. Name of respondents if not household head.....
3. Gender of the respondent
    a. Male ☐
    b. Female ☐
4. Level of education .....
5. Age .....
6. Occupation .....
7. How long have you lived in Gachagi informal settlement? .....
8. Tick the main source of your household water.

Source of water	**Rate sources according to frequency of use**
Water ponds	
Municipal tap	
Springs	
Rain water	
Buying from water vendors	

Any other specify.....

9. Do you think that the source of your water is safe or is contaminated?
   a. Safe ☐
   b. Contaminated ☐

   If contaminated name the sources of contaminants.....
10. If contaminated what would you suggest is the source of contaminant?
11. Do you think that nearness of water ponds to latrine can lead to contamination?

    If yes, how would it happen?

12. Do you think that there is any health effect of the water that you take?
13. Are there incidences of water borne diseases among the family members?
    a. Yes ☐
    b. No ☐
14. If Yes, name the water borne diseases

    .....
15. Do you boil or treat water before drinking?
    a. Yes ☐
    b. No ☐
16. If yes, is your method effective
    a. Yes ☐
    b. No ☐

17. Generally what recommendation would you give concerning water sources in Gachagi

    .....

Record Sheet

Sheet No……

Household ……

Location …….

Source of domestic water (e.g. Pond, Aquifer, Municipal tap)	
Types of water storage containers	
Related water borne diseases	
Methods of treatment	

Thank you for taking your time to complete this questionnaire.

Appendix ii: Consent

Informed consent

My name is Mwangi Ruth Wangari, I am a post graduate student at Kenyatta University, School of Environmental Studies. I am undertaking a research on Safety of drinking water in Gachagi -slum in Thika Municipality, Kiambu County. The research is purely academic and thus the information obtained will be used by government and non-governmental organizations in policy implementation necessary for access to safe drinking water.

Procedures to be followed

Participation in this study will require that I ask you some questions and also give you a questionnaire. You are free to decline to participate for any reason. You may also stop participating at any time or refuse to answer any individual questions, your decision will in no way influence any services to which you are otherwise entitled.

Discomfort and risks

Some of the questions you will be asked are private and personal and may make you uncomfortable. If this happens, you may refuse to answer them if you so choose. You may also stop participating at any time, this may take approximately ten to fifteen minutes of your time.

Benefits

If you participate in this study, you will help me fulfill the requirements for award of degree of Masters of Science. You will also benefit from the knowledge which will be obtained from the research study especially on safety of drinking water within a healthy environment.

Reward

If you agree to participate in this study 250ml bottled mineral water will be provided.

Confidentiality

The interviews will be conducted privately in your household compound. Your name will not be written on the questionnaire. The questionnaire will be kept in a safe and lockable cabinet and every information will be kept private.

Contact information

If you have any question, you may contact Dr Cecilia Gichuki on 0722926030 or Dr Manguriu on 0721348661 or Kenyatta University Ethical Committee Secretariat or Chairman at kuer@ku.ac.ke, secretary. kuerc@ku.ac.ke or ercku2008@gmail.com

Participant's statement

The above information regarding my participation in the study is clear to me. I have been given a chance to ask questions and they have been answered to my satisfaction. My participation in this study is entirely voluntary. I understand that my records will be kept private and that I can leave the study at any time. I understand that I will not be victimized at all anywhere.

Code of participant: .....

Signature or thumbprint: .....

Date: .....

Investigator's statement

I, the undersigned have explained to the volunteer in a language that she/he understands the procedures to be followed in the study and risks and benefits involved.

Name of interviewer: .....

Interviewer signature: .....

Date: .....

Recruitment of the research participants

The researcher intends to involve key informants, that are the slum village elders and gatekeepers, that is the area chief who have influence with or power over potential participants. Key-informant can identify the participants who are willing to participate in the research study. Both can either serve to facilitate contact or prohibit participation, also these will build mutual respect among the Gachagi residents and the researcher. This will enhance the elements of the appropriateness and adequacy of the information from the participants.

Appendix iii: Key Informant Interview Guide

I am Ms RUTH WANGARI MWANGI a post graduate student at Kenyatta University, School of Environmental Studies. I am undertaking a research on Safety of drinking water in Gachagi -slum in Thika Sub-County, Kiambu County. Kindly assist by giving your response to the best of your ability. Your co-operation will be treated with strict confidentiality

A) Environment Officer: Thika Sub-County

1 i) Are there any environmental awareness campaigns undertaken within Gachagi informal settlement?

ii) If Yes, what are the main challenges experienced during the awareness campaign?

iii) How often are the environmental awareness campaigns undertaken?

2 i) Does the scooping of water from the water ponds have any environmental impacts?

ii) If yes, which are they?

3 Are there environmental conservation methods introduced in Gachagi informal settlement?

4 What is the Sub-County Environment Department doing to ensure safe, healthy and sustainable environment?

5 Does the County Environment Department involve other stakeholders and private sectors in achieving a safe and healthy environment?

If yes, give examples.....

B) Public Health Officer: Thika Sub-County

1. Are there cases of water borne diseases reported from Gachagi residents?
2 i). Do the residents disclose the sources of their domestic water?
ii) If yes, which are they?
3. i) Are there some methods of water treatment introduced to Gachagi residents by Public Health Department?
ii) If Yes, which are they?
4. Have the Gachagi residents accepted any methods of treating water before drinking?
.....
5 Is there any link between water contaminants and incidences of water borne diseases among Gachagi residents?
74

C) Village Elders

1. From your observation where do most of the villagers get their water?

.....

2. i) Do you think that some of these sources have dirty water?

ii) If yes, name them.....

3. i) Do all the households have their pit latrines?

ii) If No, where you think some answer their call of nature?

4. Are there any basic heal1645th awareness campaign conducted in this village?

5. Are the villagers aware of some of the methods of treating their water before drinking?

6. Are there some residents who often complain of vomiting and diarrhoea?

7. Which are some of the precautionary measures that the villagers have taken to reduce incidences of unsafe drinking water?

Appendix iv: Plates

c. Residents washing clothes in a source of water (photo taken on 25th May 2019)

d. Household water containers at a municipal tap

Appendix v: Graduate School Authorization

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
Website: www.ku.ac.ke
P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 4150

Internal Memo

FROM: Dean, Graduate School
DATE: 19th January, 2015

TO: **Mwangi Ruth Wangari**
C/o Environmental Education Dept.
REF: N50/CE/26942/2011

SUBJECT: **APPROVAL OF RESEARCH PROPOSAL**

This is to inform you that Graduate School Board, at its meeting of 14th January, 2015, approved your Research Proposal for the M.ENV. Degree Entitled, **"Safety of Drinking Water in Gacagi Slum Thika Municipality, Kiambu County, Kenya".**

You may now proceed with your Data collection, subject to clearance with the Principal Secretary, Higher Education, science and Technology.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking forms per semester. The form has been developed to replace the Progress Report forms. The Supervision Tracking Forms are available at the University's Website under Graduate School webpage downloads.

Thank you.

ANNBELL MWANIKI
FOR: DEAN, GRADUATE SCHOOL

c.c. Chairman, Environmental Education Department

Supervisors:

1. Dr. Cecilia M. Gichuki
   C/o Environmental Education Department
   Kenyatta University
2. Dr. Daniel G. Manguriu
   C/o Environmental Education Department
   Kenyatta University

AM/cwm

Appendix vi: NACOSTI Permit

THIS IS TO CERTIFY THAT:
MS. MWANGI RUTH WANGARI
of KENYATTA UNIVERSITY, 76-1000 - THIKA,has been permitted to conduct research in *Kiambu County*

on the topic: *SAFETY OFDRINKING WATER IN GACAGI SLUM THIKA MUNICIPALITY,KIAMBU COUNTY KENYA*

for the period ending:
31st December,2015

.....
Applicant's Signature

Permit No : NACOSTI/P/15/1924/5841
Date Of Issue : 16th June,2015
Fee Recieved :Ksh 1,000

.....
Director General
National Commission for Science, Technology & Innovation

Appendix vii: Kiambu County Authorization

MINISTRY OF INTERIOR AND CO-ORDINATION OF NATIONAL GOVERNMENT
COUNTY COMMISSIONER, KIAMBU

Telephone: 066-2022709
Fax: 066-2022644
E-mail: countycommissionerkiambu@kenya.go.ke
When replying please quote

County Commissioner
Kiambu County
P.O. Box 32-00900
KIAMBU

ED.12/1/VOL.II/213

30th July, 2015

SUB-COUNTY PUBLIC HEALTH OFFICE
RECEIVED
11 AUG 2015
THIKA SUB-COUNTY

Mwangi Ruth Wangari
Kenyatta University
P.O. Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

Reference is made to National Commission for Science, Technology and Innovation letter Ref. No. NACOSTI/P/15/1924/5841 dated 16th June, 2015.

You have been authorized to conduct research on ***"Safety of drinking water in Gacagi Slum Thika Municipality, Kiambu County"*** for a period ending ***31st December, 2015.***

You are requested to share your findings with the County Director of Education upon completion of your research.

ESTHER MAINA
COUNTY COMMISSIONER
KIAMBU COUNTY

Cc County Director of Education
KIAMBU COUNTY

National Commission for Science, Technology and Innovation
P.O. Box 30623-00100
NAIROBI

Appendix viii: Ministry of Education-Kiambu County Authorization

MINISTRY OF EDUCATION SCIENCE & TECHNOLOGY
State Department of Education

Telephone:Kiambu (office) 020-2044686
FAX NO. 020-2090948
Email:directoreducationkiambu@yahoo.com
When replying please quote

COUNTY DIRECTOR OF EDUCATION
KIAMBU COUNTY
P. O. Box 2300
KIAMBU

KBU/CDE/HR/4/Vol. I/(144)

31ST July, 2015

Mwangi Ruth Wangari
Kenyatta University
P.O box 43844-00100
Nairobi.

RESEARCH AUTHORIZATION

Reference is made to the National Commission for Science Technology and Innovation letter Ref. No. NACOSTI/P/15/1924/5841 dated 16TH JUNE 2015.

This is to inform you that the above named has been authorized to carry out research on ***"safety of drinking water in gacagi slum thika Municipality,Kiambu County,"*** for a period ending 31ST December, 2015.

BETH MAINA
For: COUNTY DIRECTOR OF EDUCATION
KIAMBU COUNTY