EFFECT OF SITING BOREHOLES AND SEPTIC TANKS ON GROUNDWATER QUALITY IN SAINT BONAVENTURE TOWNSHIP OF LUSAKA DISTRICT

BY

LUKE JOHN BANDA

A dissertation submitted to the Department of Public Health, School of Medicine, University of Zambia, in partial fulfillments of the requirements for the Degree of Masters of Public Health (Environmental Health)

The University of Zambia

2013

DECLARATION

I **Luke John Banda** declare that this dissertation herein presented for the Degree of Masters of Public Health (Environmental Health) has not been previously submitted either wholly or in part for other Degree at this or any other University nor is it being currently submitted for any other Degree.

Signed: ___________________________ Date: __________________________

Luke John Banda
(Candidate)

Supervisors:

I have read this dissertation and approved it for examination

Mr. Allan Rabson Mbewe (Supervisor)

Signed: _____________________________ Date: _________________________

Department of Public Health, School of Medicine, University of Zambia

I have read this dissertation and approved it for examination

Dr. Selestine H. Nzala (Co-supervisor)

Signed: _________________________ Date: _____________________________

School of Medicine, UNZA, P.O Box 50110, Lusaka, Zambia

I have read this dissertation and approved it for examination

Dr. Hikabasa Halwindi (Co-supervisor)

Signed: _________________________ Date: _____________________________

Department of Public Health, School of Medicine, University of Zambia

COPYRIGHT

CERTIFICATE OF COMPLETION OF DISSERTATION

I, **Luke John Banda**, do hereby certify that this dissertation is the product of my own work and, in submitting it for my MPH (Environmental Health) programme further attest that it has not been submitted in part or in whole to another University.

Signature: **_________________________** Date: **_______________________**

Supervisors:

I, Allan R. Mbewe, Having submitted and read this dissertation, I am satisfied that this is the original work of the author under whose name it is being presented. I, therefore, confirm that the worker has been completed satisfactorily and is hereby ready for presentation to the examiners.

Signature: **______________________** Date: **________________________**

I, Dr. S. H. Nzala, Having submitted and read this dissertation, I am satisfied that this is the original work of the author under whose name it is being presented. I confirm that the worker has been completed satisfactorily and is hereby ready for presentation to the examiners.

Signature: **____________________** Date: **___________________________**

I, Dr. H. Halwindi, Having submitted and read this dissertation, I am satisfied that this is the original work of the author under whose name it is being presented. I, therefore, confirm that the worker has been completed satisfactorily and is hereby ready for presentation to the examiners.

Signature: **____________________** Date: **___________________________**

Head of Department

Signature: _______________________ Date: ________________________

Department of Public Health, School of Medicine, University of Zambia

CERTIFICATE OF APPROVAL

This dissertation of **Luke John Banda** is approved as fulfilling the requirement for the award of the Degree of Masters of Public Health (Environmental Health) by the University of Zambia.

Examiner I

Signature: ________________________________

Date: ____________________________________

Examiner II

Signature: ________________________________

Date: ____________________________________

Examiner III

Signature: __________________________________

Date: ______________________________________

ABSTRACT

The rapid population growth of Lusaka has brought adverse effects on water supply and sewage treatment facilities in the District. Consequently, authorities in Lusaka have allowed use of septic tanks and boreholes in the same area in some Townships. St. Bonaventure located about 7km from Town center to the south in Makeni is one of such areas. Lusaka City is built on a marble which is cut by a network of fissures that are open hollows or filled with soil. This reduces the attenuation of pollutants that would occur through natural filtration. A study on groundwater that was conducted in 2010 in selected areas of Lusaka showed high levels of contamination with bacteria.

The general objective of the study was to assess the effect of siting boreholes and septic tanks in the same area on the quality of groundwater in St. Bonaventure Township. Specific objectives were to determine the effect of distance between boreholes and septic tanks on groundwater quality in St. Bonaventure Township and to assess the effect of siting boreholes and septic tanks in relation to direction of groundwater flow on groundwater quality. The study site was purposively selected because all households in the Township used septic tanks and boreholes for human waste treatment and drinking water supply respectively. The study population, therefore, included all the 490 households in the study site. A sample size of 55 households was found at 95% confidence level using EPI INFO version 7 at expected frequency of 20%.

The majority (67.27%) of water samples collected from households in St. Bonaventure were satisfactory, while 32.72% were unsatisfactory. The study revealed that only direction of groundwater flow had an association with water quality (total coliform and feacal coliform) at 5% significance level with p-values equal to 0.001 and less than 0.001 respectively. Distance from borehole to soakaway was insignificant in the quality of water. In conclusion, siting boreholes and septic tank systems in the same area was not suitable for St. Bonaventure Township and Lusaka at large because safety of groundwater cannot be guaranteed. Partners in water resource management such as ZEMA, Department of Water Affairs, Geological Department and Lusaka City Council should, therefore, work together each time projects that involve groundwater development and onsite wastewater treatment are to be implemented. LWSC to provide piped water and sewage services to St. Bonaventure.

DEDICATION

This work is dedicated to my parents who trained me to be honest and resilient even in situations that are challenging and to my two sons Eugene and Surge for allowing me to be away from them for a long period of time.

ACKNOWLEDGEMENTS

I wish to express my gratitude to my sponsor, the University of Zambia for enabling me undertake this study of Masters of Public Health (Environmental Health) Degree without whom it would have been very difficult to achieve. I would like to acknowledge my supervisors Mr. Allan Rabson Mbewe, Dr. Selestine H. Nzala and Dr. Hikabasa Halwindi without whose guidance this study would have been impossible to achieve.

I would like to thank Mr. Y. Siulapwa for the guidance in the selection of the research topic and Mr. A. Nguluwe for his contribution during research proposal development.

I would like to acknowledge the Lusaka City Council for facilitating the research process and finally the Research Assistants Juanita Ntemba Mumba, Nang'amba Nachombe and Obvious Nchimunya for braving the scorching heat from the sun during data collection.

ABBREVIATIONS/ACRONYMS

E. coli	:	Escherichia coli
LCC	:	Lusaka City Council
LWSC	:	Lusaka Water and Sewerage Company
OWTS	:	Onsite Wastewater Treatment System
TC	:	Total coliforms
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UNHCR	:	United Nations High Commission for Refugees
VIP	:	Ventilated Improved Pit latrines
WHO	:	World Health Organization
ZEMA	:	Zambia Environmental Management Agency

Table of Contents

Item .... Page
Declaration i
Copyright ii
Certificate of completion of Dissertation iii
Certificate of Approval iv
Abstract v
Dedication vi
Acknowledgements vii
Abbreviations/Acronyms viii
Table of Contents ix
List of Tables xi
List of Figures xi

CHAPTER ONE 1
1.0 INTRODUCTION 1
1.1 Background information 2
1.2 Problem statement 4
1.3 Justification of the Study 6
1.4 Research Objectives and Hypotheses 7
1.4.1 General Objective 7
1.4.2 Specific Objectives 7
1.4.3 Research Hypotheses 8
1.5 Operational Definitions 8

CHAPTER TWO 10
2.0 LITERATURE REVIEW 10
2.1 Historical Development of Human Waste Treatment 10
2.1 Types of On-site Waste Water Treatment System 10
2.2.1 Septic Tanks and Aqua Privies 11
2.3 Construction, Operation and Maintenance of Septic Tanks 12
2.3.1 Use and Maintenance of Septic Tank System 12

2.4 Location, Construction and Legal Obligations of Boreholes 13
2.4.1 Standards for Drinking Water 14

CHAPTER THREE 16

3.0 METHODOLOGY 16

3.1 Study Design 16
3.2 Study Setting 16
3.3 Dependent and Independent Variables 16
3.4 Inclusion Criteria 17
3.5 Exclusion Criteria 17
3.6 Sample Size 18
3.7 Sampling Procedure 18
3.8 Data Collection, Management and Quality Control 19
3.9 Ethical Consideration 20
3.10 Data Analysis 21

CHAPTER FOUR 22

4.0 PRESENTATION OF FINDINGS 22

4.1 Microbiological Quality of Groundwater 22
4.2 Siting of Boreholes in Relation to Septic Tanks/soakaway 23
4.3 Operation and Maintenance of Septic Tanks/soakaway 24
4.4 Association between Dependent Variable and Independent Variables 25
4.4.1 Chi-square Test Results 26
4.4.2 Logistic Regression Analysis Results for Total and Faecal Coliforms 26

CHAPTER FIVE 29

5.0 DISCUSSION OF FINDINGS 29

5.1 Location of Boreholes in Relation to Direction of Groundwater Flow 29
5.2 Distances between Boreholes and Soakaways 30
5.3 Other Factors Associated with Groundwater Quality 31
5.4 Limitations of the Study 34
5.5 Conclusion and Recommendation 35

6.0 REFERENCES 37
7.0 APPENDICES 41
7.1 Information Sheet 41
7.2 Consent form 43
7.3 Data Collection Tools 45
7.4 Permission Letters 49
7.4.1 Permission Letter from Assistants Dean Post Graduate Studies 49
7.4.2 Permission Letter from Lusaka City Council 50
7.5 The UNZA Biomedical Research Ethics Committee Approval Letter......... 51
7.6 Water Analysis Laboratory Results 52

List of Tables

Table 1: Total Coliform in Groundwater Samples from Different Sites in Lusaka 5
Table 2: *E. coli* in Groundwater Samples from Different Sites in Lusaka 5
Table 3: Standards for Bacteriological Quality of Drinking Water 15
Table 4: Dependent and Independent Variables 17
Table 5: Sampling Fraction 19
Table 6: Groundwater Quality 22
Table 7: Operation and maintenance of Septic Tanks Systems 24
Table 8: Water Quality and Direction of Groundwater Flow 25
Table 9: Water Quality and Distances from Water Sources to Soakaways 26
Table 10: Logistic Regression Model for Total Coliform as a Dependent Variable 27
Table 11: Logistic Regression Model for Feacal Coliform as a Dependent Variable 28

List of Figures

Figure 1 Households with Individual Water Storage Tanks 1
Figure 2: Location of Borehole in relation to Distance from Soakaway 23
Figure 3: Location of Boreholes and Soakaways in Relation to Direction of Groundwater Flow 23

CHAPTER ONE

1.0 INTRODUCTION

The rapid population growth in Zambia and Lusaka in particular has brought a number of adverse effects on the delivery of public health services which include sewage treatment and water supply. In 1964, at the attainment of political independence, the population of Lusaka was 195,700 (Kawanga, 2003). In addition, according to Central Statistical Office (2000), the population of Lusaka in 2000 was estimated at 1,391,329 and this has continued to grow over the past 10 years. The current Lusaka's population is estimated at 2,198,996 in accordance with Central Statistical Office (2011).

Resulting from this problem, authorities in Lusaka district have allowed the use of septic tank system as a means of human waste (excreta) treatment and disposal in some townships. St. Bonaventure Township (study site) has a total number of 490 households, located in Lusaka's Makeni area about 7km from town centre in the south. In this Township on-site treatment of wastewater is practised and private boreholes are the only source for domestic drinking water supply.

Figure 1: Households with Individual Water Storage Tanks

Source: Nachombe (2013)

According to Gideon et al, (2004), on-site wastewater treatment systems are point sources of pollution, therefore, they are expected to exert greatest impact on groundwater sources in their vicinity. Where there are a large number of on-site wastewater treatment systems the overall impact may be widespread. For the purpose of this study, however, on-site wastewater treatment system will be restricted to septic tanks and their soakaways.

1.1 Background Information

In many places, particularly in areas with low population densities, it is common to store and treat wastewater on-site where it is produced. To do this, there are a number of technical options for on-site waste management which if designed, constructed, operated and maintained correctly will provide adequate service and health benefits when combined with good hygiene practices. On-site systems include: ventilated improved pit latrines (VIP), pour-flush toilets and septic tanks. Building and operating these systems is often much less expensive than off-site alternatives. Some on-site sanitation systems such as septic tanks and pit latrines, however, in densely packed urban areas require sludge to be pumped out and treated off-site as compost which is used as a fertilizer after it has been stored under suitable conditions to kill worm eggs and other pathogens (WHO, 2006).

A typical on-site wastewater treatment system (OWTS) consists of a septic tank with a soil absorption field that allows treated effluent (settled sewage) to infiltrate into the soil. These systems when functioning well are effective at removing pollutants before they enter into the environment. This process, however, depends on certain circumstances such as geological and climatic conditions. The release of pollutants into the environment may result if a septic system is improperly sited and constructed (Obropta and Berry, 2005).

In addition, failure to adequately address issues of wastewater treatment and disposal can lead to serious public health and environmental problems. The cost of providing conventional sewage collection and treatment facilities can be high and it may not be economically feasible, particularly in sparsely populated areas. In these circumstances, on-site treatment of sewage becomes logical alternative as they have become a common feature in most rural and peri-urban areas. In this regard, septic tank and soakaway disposal systems are the most widespread due to their simple operation and maintenance procedures. Despite the seemingly low technology of these systems, failure is common and it can lead to significant adverse impacts. It is, therefore, imperative that stringent compliance criteria and management practices are adopted in regards to their treatment performance with reliable strategies taken to ensure householder compliance to these standards (Goonetilleke, et al 2002).

According to McQuillan (2004), conventional septic tanks and soakaway are suitable means for on-site sanitation when lot (piece of land) size and subsurface conditions provide adequate natural means of reducing pathogenic organisms and organic matter. Septic tank effluent can also be lost through evapo-transpiration or prevented by geologic barriers from seeping into some aquifers. Widespread groundwater contamination, however, has occurred in many rural areas utilizing on-site wells and septic tank systems. This is because of effluent discharged onto the subsurface by soakaways as this often percolates into the same aquifer tapped by wells for domestic supply. In the some cities, on-site septic systems have been reported to have contaminated more public and private water supply wells, than all other sources combined.

In the United States, about 34% of those served by a public water system utilize groundwater source. Although originally thought to be clean and safe, groundwater may be subject to a variety of chemical and microbiological contaminants. There are approximately 25 million domestic septic tanks (20-25% of all households) in the U.S with about 400,000 new ones installed each year. However, septic tanks have been previously associated with groundwater contamination events in the U.S. and continue to be of concern with regard to groundwater protection (Reynolds and Barrett, 2003). Overall, about 75% of the U.S. population is connected to municipal wastewater collection and treatment systems. The remaining 25% use on-site wastewater treatment systems to treat their wastewater. According to Simms (2006), up to 40% of wastewater associated with new home construction in U.S. is discharged to on-site systems and hence these systems treat and release vast amounts per day into the environment. In Africa, a study on pollution of groundwater that was conducted in Kwale District in Kenya by Tole in 1997 revealed that 13% of boreholes that were sampled were contaminated with *E. coli* an indication of faecal contamination.

In Zambia, septic tanks are generally common in areas without sewer lines. In Lusaka, mass media complex, Chalala and St. Bonaventure the study site are some examples of areas where septic tanks are used for sewage disposal. The City of Lusaka, however, is built on a marble which is cut by a network of fissures that remain either as open hollows or filled with soil. These fissures manifest themselves on the surface as pits and caves. The presence of these fissures in marbles makes them very vulnerable and susceptible to wide range of environmental factors (Grönwall et al, 2010).

According to Grönwall et al. (2010), the limestone landscape which is characterized by caves, fissures and underground streams reduces and/or eliminates completely the attenuation of pollutants that would otherwise occur through natural filtration. Groundwater is, therefore, essentially as easily polluted as surface water, especially in Lusaka's low-income settlements. This makes water quality a major health problem, particularly during the rainy season, where Cholera outbreaks linked to faecal- oral route transmission are common.

1.2 Problem Statement

In Zambia septic tanks are used in areas that are not serviced with sewer lines. In Lusaka, septic tanks are in common use in areas like mass media complex, Chalala and St. Bonaventure. According to UNESCO (2003), vacuum tanker services in Lusaka are greatly overwhelmed by demand in that only about 40 % of the requests are processed in a year. The eminent hazard of the 60 % of unserviced septic tanks reduces the efficiency of sedimentation and fermentation processes, thereby facilitating overflow and percolation of effluent with pathogenic bacteria and cysts into deeper levels of the ground and subsequently into the groundwater bearing stratum.

A study on groundwater that was conducted in 2010 showed high levels of contamination of groundwater with bacteria in selected areas of Lusaka. Statistics showed that about 60% of these groundwater sources had levels of contamination above 10 *Total coliforms* per 100ml of water; while 30% showed presence of *E. coli* which is an indicator of faecal contamination (Andrea et al, 2010). Tables 1 and 2 give details of different levels of contamination in boreholes and wells in selected locations of Lusaka district.

Table 1: Total Coliform in Groundwater Samples from Different Sites in Lusaka

No	Number of Total Coliforms (TC) found in 100ml of Water	Number of Boreholes	Relative frequency (%)
1	0 - 10	35	40
2	≥ 11	53	60
Total		**88**	**100**

Source: Andrea et al., (2010)

Table 2: *E. coli* in Groundwater Samples from Different Sites in Lusaka

No	Number of *E. coli* Found in 100ml of Water	Number of Boreholes	Relative frequency (%)
1	0	62	70
2	≥ 1	25	30
Total		**88**	**100**

Source: Andrea et al., (2010)

Despite this problem, Lusaka City Council has allowed use of septic tank system as a means of treatment and final disposal of human excreta. St. Bonaventure is one of the Townships in Lusaka where septic tanks are used to treat human excreta and boreholes as the only source for drinking water in the same locality.

This situation could be an indication that there is inadequate enforcement of guidelines to guide housing developers so that effluent from septic tank system does not pollute groundwater. This could also be attributed to limited information on effect of septic tank system on groundwater quality. Consequently, it is expected that if this practice continues, Lusaka may experience serious and devastating outbreak of preventable diarrhoeal diseases due to contamination of groundwater which is perceived to be the safest drinking water source. According to Dissanayake et al, (2004), 80% of sicknesses and deaths among children in the world are caused by unsafe drinking water. WHO (2003) also states that on average, every 8 seconds in the world, a child dies because of drinking contaminated water. Zambia and Lusaka in particular is not an exception; if this practice is allowed to go on without taking corrective measures, sicknesses and deaths that have been highlighted at global level as a result of drinking contaminated water, will be even worse locally.

1.3 Justification of the Study

Most studies that have been conducted in Lusaka have directed their focus on contamination of wells with waste from pit latrines in slums. No serious studies have been conducted in low density areas because it is perceived that borehole water is safe without relating it to use of septic tank system in the same area. Some studies have also concentrated on the need for Lusaka residents to use borehole water as a safe alternative source of drinking water and other domestic uses because Lusaka Water and Sewerage Company is unable to meet the demand for the commodity.

Although low density areas have not been considered for such studies, a study that was conducted in selected areas of Lusaka in 2010 showed high levels of bacterial contamination. According to the results of the study, about 60% of these selected groundwater sources had levels of bacterial contamination ranging from 100 to 1,020 total coliforms per 100ml of water; while 30% showed presence of *E. coli* which is an indicator of faecal contamination (Andrea et al, 2010).

These levels of contamination could be due to the fact that the City of Lusaka is built on a marble which is cut by a network of fissures that remain either as open hollows or filled with soil. According to Grönwall et al. (2010), the marble is characterized by caves, fissures and underground streams. These characteristics reduce and/or eliminate completely the ability of such ground formation to naturally reduce pollutants in the water that flows through it. This also makes it easy for groundwater to be polluted like surface water. This, therefore suggests that there is a high probability of bacterial contamination of groundwater in St. Bonaventure because it is located within Lusaka catchment area, hence the need to conduct this study.

A study of this nature which is designed to assess the effect of siting boreholes and septic tanks in the same area on groundwater quality in Lusaka's St. Bonaventure Township is important because Lusaka is expanding at a very fast rate. This expansion has outstripped the capacity of Lusaka Water and Sewerage Company to provide appropriate sewerage and water supply services. This has thus forced housing developers to use septic tanks and boreholes for wastewater treatment and drinking water respectively. The unfortunate thing is that this expansion has not been accompanied with comprehensive studies on the effects that such development may have on groundwater.

In addition, this study has a bearing on policy makers, training institutions and researchers on use of septic tanks and boreholes in selected locations of Lusaka City Council catchment areas and other parts of Zambia. The information that has been generated will be used to support studies both on small and larger scale, hence adding to the body of knowledge. At the time of conducting this study it was not easy in Zambia to access information on similar studies especially with a public health connotation. Studies that have been conducted in this area are mainly on water engineering without specific linkage to public health. This study provides a clear link between water and sewage engineering and their effects on public health in general. Ordinary citizens will be enlightened on problems that may come with the use of septic tanks and boreholes in the same location. This will ease the work of city planning authorities since they will be dealing with the public that is aware about both public health and engineering requirements in the use of septic tanks and boreholes on the same piece of land.

The findings of the study will, therefore, be made available to all partners so that recommendations are implemented by both the utility companies (Water and Sewerage Companies) and the law enforcement institutions such as Lusaka City Council and Zambia Environmental Management Agency (ZEMA). This is also going to benefit the residents of Lusaka and the country at large by protecting groundwater and hence promoting public health.

1.4 Research Objectives and Hypothesis

1.4.1 General Objective

The general objective of the study was to assess the effect of siting boreholes and septic tanks in the same area on the quality of groundwater in St. Bonaventure Township

1.4.2 Specific Objectives

(i) To determine the effect of distance between boreholes and septic tanks/soakaways on groundwater quality in St. Bonaventure Township

(ii) To assess the effect of siting boreholes and septic tanks/soakaways in relation to direction of groundwater flow on the groundwater quality in St. Bonaventure Township

1.4.3 Research Hypothesis

The purpose of this study was to assess the effect of siting boreholes and septic tanks/soakaways in the same area on groundwater quality in St. Bonaventure Township. This is the area where septic tank system is the only means of treating and disposing wastewater and boreholes are the only source for drinking water. The null hypothesis and the alternative hypothesis were:

Ho: There is no association between siting boreholes and septic tanks/soakaways in the same area and quality of groundwater in St. Bonaventure Township

Hi: There is association between siting boreholes and septic tanks/soakaways in the same area and quality of groundwater in St. Bonaventure Township

1.5 Operational Definitions

The following operational definitions applied to this study:

Wastewater: Means water comprising liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations

Aqua Privy: Means a small septic tank located directly below a squatting plate which has a drop pipe extending below the liquid level in the tank to form a simple water seal

Soakaway: Means deep hole in the ground covered with a solid concrete lid and a pipe leading into the hole enabling any excess water to drain away into the earth's strata.

Septic Tank: Means a small-scale sewage treatment system common in areas with no connection to main sewage pipes provided by local governments or private corporations.

Sludge: Means residual, semi-solid material left from industrial wastewater or sewage treatment processes.

Desludging Septic Tank: Means removal of sludge (semi-solid material) from the bottom of the Septic tank when it takes up 30 percent on the volume of the septic tank.

On-site wastewater Treatment system: Means treatment of human excreta at the place where it is generated, stored and disposed off without transporting it to a central sewage treatment facility.

Satisfactory: Means groundwater which has faecal coliform /*E. coli* count of zero per 100ml or total coliform count of not more than 10 per 100 ml

Unsatisfactory: Means groundwater which has any presence of faecal coliform/*E. coli* or a total coliform count of more than 10 per 100 ml

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter is presented in four (4) sections. The first section is on the historical development for on-site wastewater treatment facilities. The second section deals with types of on-site wastewater treatment facilities that are used in different parts of the world. The third section is on issues related to public health requirements in construction, operation and maintenance of on-site wastewater treatment facilities. Finally, the fourth section is about location, construction and legal obligations of boreholes.

2.1 Historical Development of Human Waste Treatment

King Minos installed the first known water closet with a flushing device in the Knossos Palace in Crete in 1700 BC. In the intervening 3,700 years, societies and governments that served them had sought to improve both the removal of human wastes from indoor areas and the treatment of waste to reduce threats to public health and ecological resources. The Greeks, Romans, British, and French achieved considerable progress in waste removal during the period from 800 BC to AD 1850. The removal of waste, however, often meant discharge to surface waters a practice that led to severe contamination of lakes, rivers, streams and coastal areas. This resulted into frequent outbreaks of diseases like Cholera and Typhoid Fever (Gilbert, 2008).

In the middle of 20th century, septic tanks were used for primary treatment of wastewater and their effluent was discharged into gravel-lined subsurface drains (Kreissl, 2000). In 1877, Schlössing and Muntz demonstrated that oxidation in soils was due to an organized fermentation that could be described as the treatment processes occurring through microbial films. The impact of this discovery on public health could be best understood by examining the consequences of its absence (Bishop, 2011).

2.2 Types of On-site Wastewater Treatment System

The general principles of design and operation of on-site systems are generally those in which excreta and anal cleansing materials are deposited directly into some sort of container, most commonly a subsurface tank. The risk of contamination from collection of waste at a single point depends largely on the design of the facility (ARGOSS, 2002). On-site wet systems also typically require some form of soakaway to dispose of excess effluent and this may increase risks from both pathogens and nitrates (ARGOSS, 2001). Despite the possibility of groundwater being contaminated with disease causing organisms from on-site wastewater treatment systems, research suggests that within a relatively short period of time a biologically active layer forms around the active layers of the pit and forms a mat of gelatinous material of predatory bacteria and fungi which removes pathogenic microorganisms (Chidavaenzi et al, 2000).

2.2.1 Septic Tanks and Aqua Privies

Aqua privies are essentially limited to single or a few dwellings. Septic tanks and aqua privies operate by initial deposition of excreta into an impermeable tank with overflow of excess liquid into a soakaway. In some cities, such as Hanoi in Vietnam, the effluent enters the surface water drainage system. In both technologies, the sludge is retained under water and this must be maintained to reduce offensive odours. Septic tanks are usually located at a distance from the toilet and water is used to flush excreta into the tank (Lerner, 1996). In the aqua privy, the tank is located just below or adjacent to the toilet. Water requirements are often lower than for septic tank systems, but the tank requires periodic addition of water to ensure water seal is maintained. Inside the tank of septic system and aqua privies, solids settle at the bottom of the tank; a scum forms a crust on the surface. As the tank fills with liquid, the overflow is channeled out of the tank to the soakaway (WHO, 2006).

The destruction of pathogens via predation, attenuation and thermophilic or natural occurs in the tank and drainage field, but this may be incomplete especially for viruses. This may result from high flow rates which may reduce the period of contact for predation and attenuation from low clay content which reduces the potential for absorption. Disease outbreaks associated with inadequately sited, maintained, overloaded and malfunctioning septic tanks have been documented (Scandura and Sobsey, 1997). When assessing risks from septic tanks and aqua privies, it is, therefore, important to note that there are two distinct components that must be managed namely; tanks containing sludge which must be impermeable and properly maintained. These require periodic inspection which is most easily performed immediately after emptying. In addition, the soakaways should be properly located and designed, taking into account infiltration rates of the soil, depth to groundwater and its velocity, direction and distance to the nearest groundwater source used for supply of drinking water.

2.3 Construction, Operation and Maintenance of Septic Tanks

A septic tank is a large underground, watertight container, although the size of the tank is legally determined by the number of bedrooms in the house, it is about 2.7m long, 1.2m-1.5m wide and 1.5m deep and connected to the sewer line. They are mainly rectangular but may be cylindrical made of concrete or fiberglass (Vogel, 2005). Reinforced concrete tanks, however, have traditionally been used for septic tanks. This is reflected in the amount of information available regarding concrete tanks relative to tanks made of other materials. Concrete tanks are readily available, generally lower in cost than alternative materials and have proven to be reliable (University of Minnesota, 2011).

The use of septic tank is viable in areas where soils contain relatively high concentration of organic matter and infiltration rates are 10-50 litres/m^2 per day. This is, however, dependent on the distance to the nearest groundwater source and depth of water table. It is important to bear in mind that soakaway will eventually become clogged and a new site developed. There should always be a minimum distance to the water table beneath the base of soakaway of not less than 1.2 m (WHO, 2006). According to Sevebeck and Kroehler (1992), the need for proper siting, installation, and maintenance is key to keeping a septic system functioning well. This is because a conventional septic tank can last for as long as 50 years if the homeowner maintains it properly.

2.3.1 Use and Maintenance of Septic System

Many homeowners using septic tank system do not know what it is or how it should be maintained. Proper maintenance and regular pumping are vital to avoiding septic tank system packing-ups that may lead to expensive repairs (Obropta and Berry 2005). Thus with appropriate use and proper maintenance, a system that has been properly sited and installed can work effectively for many years. While a conventional septic system has no moving parts and normally does not require weekly or monthly maintenance, thus attention must be paid to some general principles of maintenance. Important maintenance practices include: minimizing water use, pumping septic tank regularly, inspecting the system at each pumping, providing adequate site drainage and use of proper landscaping (Sevebeck and Kroehler, 1992).

Failure to have the septic tank pumped out regularly is one of the most frequent causes of damage to the system. According to Phil (2012), the frequency of emptying of sewage sludge from a septic tank will vary depending on a number of factors. These factors would include the number of persons occupying the house that discharges sewage into the system, the capacity of the system and the treatment process within the system. Carrying out an examination of the system at least once a year, including dipping the tank, is the most practical method of determining if sludge needs to be removed from the system. Sevebeck and Kroehler (1992), states that septic tanks should be pumped out every three (3) to five (5) years by a reputable septic tank service contractor.

According to Vogel (2005), the owner should know the age, capacity and location of both septic tank and soakaway. The system should be inspected and pumped out by a qualified professional. Similarly, water usage should be reduced by avoiding water intensive activities such as running dishwasher and washing machine simultaneously. Soakaway should be kept clear of trees, automobiles and heavy equipment to avoid compaction of the soil around it. In addition to these practices, Vogel (2002) indicates warning signs of a failing septic tank system which include: a septic tank that has not been pumped in the last five years, defective flushing system, liquid ponding over the absorption field, growth of green vegetation over the absorption field, unpleasant oduors near the field and effluent or wastewater seeping into the basement.

2.4 Location, Construction and Legal Obligations of Boreholes

It is good practice to site a borehole as far away as possible and preferably upslope from any potential sources of pollution such as septic tanks and soakaways. A minimum distance of 50 metres between a water borehole and any potentially polluting activity is recommended (Natural Environmental Research Council, 2011). Contrary to this, UNHCR (2006) sets the minimum distance between a borehole and any potentially polluting activity at 30 metres.

According to Rusinga (2004), safe location of the borehole or well requires a careful consideration of factors which affect water quality such as surface drainage, groundwater flow and technology being used to abstract water. Motorized pumps for instance abstract groundwater in very large volumes and this is usually only limited by the delivery capacity of the aquifer being pumped. Thus during groundwater abstraction, it moves towards the abstraction point from much further away points than for similar cases when using manually operated pumps. This implies that separation distances for potentially contaminating activities need specific assessment for boreholes and wells that are equipped with motorized pumps.

Similarly, in the case of boreholes abstracting from superficial deposits, the top few metres should be encased and this depends on the aquifer thickness at the site. A borehole abstracting water from a bedrock aquifer should be sealed off through the superficial deposits by installing a length of plain casing to at least 5 m below the upper surface of the bedrock. The casing should be grouted effectively in order to minimise the risk of poor quality surface or shallow groundwater entering the borehole (Natural Environmental Research Council, 2011).

2.4.1 Standards for Drinking Water

The coliform group is made up of bacteria with defined biochemical and growth characteristics that are used to identify bacteria that are more or less related to faecal contaminants. The Total coliforms represent the whole group, and these are bacteria that multiply at 37ºC. In the thermotolerant coliforms, these are bacteria that can grow at a higher temperature of 44.2ºC and *Escherichia coli (E. coli)* is one of the thermotolerant species that is specifically of faecal origin (WHO, 2001).

Table 3: Standards for Bacteriological Quality of Drinking Water

No	Type of Water Source	Organisms	Guideline Value
1	All water intended for drinking	*E. coli* or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
2	Untreated water	*E. coli* or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
		Total coliform bacteria	Must not be more than 10 in 100 ml of water sample
3	Treated water entering the distribution system	*E. coli* or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
		Total coliform bacteria	Must not be detectable in 100 ml of water sample
4	Treated water in the distribution system	*E. coli* or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
		Total coliform bacteria	Must not be detectable in any 100 ml of water sample. In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period

Source: WHO (2001); Food and Drugs Act Cap 303 (1995)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Design

This was a cross-sectional study, with respondents drawn from fixed point in time. The relevant information which was obtained was then classified as having or not having the attribute of interest. In this case water quality was the main subject of investigation, thus water samples were analysed in the laboratory to ascertain its microbiological quality and results were classified as either satisfactory or unsatisfactory.

The study has also collected information on both groundwater quality and potential risk factors that may determine the quality of groundwater. These risk factors include siting of septic tanks and soakaways in relation to source of drinking water supply (i.e. distance from soakaway to water source and direction of groundwater flow in the area).

3.2 Study Setting

The study was conducted in St. Bonaventure Township of Lusaka District. The study site was purposively selected because all households in the Township use septic tanks and boreholes for their human waste treatment and drinking water supply respectively. The study population included 490 households in St. Bonaventure that were classified under high and medium cost plots.

3.3 Dependent and Independent Variables

This section describes the two types of variables in the study which include dependent (response) variable and independent (explanatory) variables as can be seen in table 4.

Table 4: Dependent and Independent Variables

Variable	Indicator	Scale of Measure	
Dependent Variable			
Bacteriological water quality	• Number of Faecal coliforms/*E. coli* in 100mls of water	• Satisfactory: Nil • Unsatisfactory: Any presence	• Ordinal
	• Total coliform in 100mls of water	• Satisfactory: 0 to 10 cells • Unsatisfactory: More than 10 cells	• Ordinal
Independent Variables			
Siting of septic tanks and water sources	• Location of drinking water source in relation to soakaway in terms of direction of groundwater flow	• Safe: Up-slope • Not safe: Down-slope	• Ordinal
Distance between soakaway and borehole	• Location of borehole in relation to soakaway in terms of distance	• Far: ≥ 30 m • Near: < 30m	• Ordinal
Condition of septic tank	• Record of desludging	• At least once in 3-5 years	• Ordinal
	• Smell on opening the tank	• No foul smell	• Ordinal
Pump type	• Motorized • Manually operated	• High influence • Low influence	• Ordinal
Water use	• Activities requiring heavy watering	• Present • Absent	• Nominal

3.4 Inclusion Criteria

- All households that had boreholes for drinking water and septic tanks for wastewater treatment

3.5 Exclusion Criteria

- All households without boreholes and septic tanks in St. Bonaventure Township

3.6 Sample Size

EPI INFO version 7 was used to calculate the sample size from a total population of 490 households, and using the expected frequency of 20% (bacteriological contamination of groundwater), a sample size of 55 households was found at 95% confidence level. The number of households was assumed to be equal to the number of boreholes and septic tanks in St. Bonaventure.

3.7 Sampling Procedure

The sample for households was randomly selected from St. Bonaventure Township using stratified systematic sampling. The process of procuring sample for this study applied a probability stratified method of sampling which was followed by systematic sampling of households from each stratum. Strata were defined by one major characteristic which was the size of plots on which households were located.

St. Bonaventure residential site has a total number of 490 households comprising two specific plot sizes. The plots are classified under medium plots (30 x 45) which consist of 223 households while high cost (35 x 50) has 267 households. The importance of plot sizes was on assumption that they might have effect on siting of water sources and septic tank systems within the plot boundaries. It was therefore, important to employ stratified sampling method in order to capture these specific subgroups within the study population. This technique was useful because it ensured the presence of key elements in the sample. After stratification according to plot sizes, households in each stratum were listed and the first household was randomly picked from the list. To achieve this, the total number of households in each stratum was divided by the sample size using the formula:

$$k = \frac{N}{n}$$

Where k = sampling interval,

n = sample size

N = population size

Thus, k = 490/55 and finally, k = 9.

This meant that the starting point was any number from 1 to 9 on each list. Households that corresponded to numbers from 1 to 9 on the two lists were subjected to a draw and the starting point was determined. After the first number was picked, every 9th household was selected. At the end of the procedure, 30 households from high cost and 25 households from low cost were selected (refer to table 5). In the event that the respondent declined to be part of the study, the next household was picked. In the case where the owner of the picked household happened to be absent at the time of the study, the household was revisited. Similarly, if on the second visit the owner was absent, the respondent was replaced with the next household.

Table 5: Sampling Fraction

Stratum	**Determination of Sample Size in relation to Housing Units**	
	High Cost plots	Medium Cost Plots
Population Size	267	223
Sampling Fraction	1/9	1/9
Final Sample Size	30	25

3.8 Data Collection, Management and Quality Control

Prior to data collection, a training programme for three Research Assistants was conducted by the Principal Investigator of which two were Environmental Health Officers and one Environmental Health Technologist. They were all trained in data collection techniques, water sampling techniques, use of modified sampling form, inspection guide and how to physically measure and record the distance between the borehole and the septic tank/soakaway. This was done in order to ensure that data collected was reliable and trustworthy.

Water samples for bacteriological analysis were collected from boreholes in the households that participated in the study. When the research team reached a household, the water tap was first sterilized by a flame from cotton wool soaked in methylated spirit as the source of heat. After sterilization, the tap was opened and allowed to run for 30 seconds and thereafter 300mls of water was collected in sterile bottles which were sterilized at Environmental Engineering

Laboratory (EEL) in the School of Engineering at the University of Zambia. Samples were transported to EEL every day at the end of the activity in a cold box containing frozen ice packs. This was done to ensure that water samples were taken to the laboratory in the same state as at the time of collection. An inspection guide was used to check on the environmental conditions around septic tanks and soakaways. Direction of groundwater flow around St. Bonaventure was collected from the Department of Water Affairs in Lusaka District. This was recorded in relation to siting of each borehole and the nearest septic tank/soakaway. A 100 metre tape measure was used to physically measure the distance between each selected borehole and the nearest soakaway. Where the nearest soakaway to the sampled borehole was in the neighbourhood, the distance between the borehole in the selected household and the soakaway in neighbourhood was measured.

3.9 Ethical Considerations

Ethical clearance from the University of Zambia Biomedical Research Ethics Committee was sought and a written permission from Lusaka City Council was obtained. Verbal consent was also sought from the head of households. Anonymity, confidentiality and privacy were upheld during and after carrying out the research by not indicating names of individuals who were owners of households that participated in the study on sampling form and inspection guide. The purpose, nature and benefits of the study were explained to participants. There were no notable risks that participants could be exposed to for participating in the study. Water analysis results would mainly enable them take corrective measures in case their water was contaminated, hence benefiting from the study. The preliminary microbiological results of water analysis were released to the owners in households where unsatisfactory results were recorded and those who demanded the out-come of analysis of their water when samples were collected. Advice on corrective measures was given to household owners at the time of communicating results. Corrective measure included chlorination of all water to be used for domestic purposes and boiling for drinking purposes.

3.10 Data Analysis

Stata version 11 and SPSS computer packages were used for both data entry and analysis. Results of microbiological water analysis and observations on the inspection guide were coded. Numerical numbers were assigned to observations prior to being entered into the software. Pearson chi-square test and Logistic regression model were employed to determine whether there was association between bacteriological water quality and distance from water source to soakaway and location of water source in relation to direction of groundwater flow with respect to soakaway. P values of less than 0.05 were considered statistically significant in order to reject the null hypothesis.

CHAPTER FOUR

4.0 PRESENTATION OF FINDINGS

A total of 55 households were visited for water sample collection, inspection of general surroundings to check the type of finishes and inspection of septic tank systems to determine the conditions of septic tanks and soakaways. Variables have been presented according to the layout on sampling form and inspection guide. Some of these variables have been grouped in order to give the overall picture. Similarly, findings have been presented in different forms that comprise frequency tables, charts, cross tabulations and logistic regression model.

4.1 Microbiological Quality of Groundwater

The microbiological indicators used in this study, namely Total Coliform, Faecal coliform and *Escherichia coli* (*E. coli*), can be seen in table 6.

Table 6: Groundwater Quality

Type of Contaminants	Quality of Water		Total
	Satisfactory	Unsatisfactory	
Total coliform	37 (67.3%)	18 (32.7%)	**55 (100%)**
Faecal coliform	37 (67.3%)	18 (32.7%)	**55 (100%)**
E. coli	49 (89.1%)	6 (10.9%)	**55 (100%)**

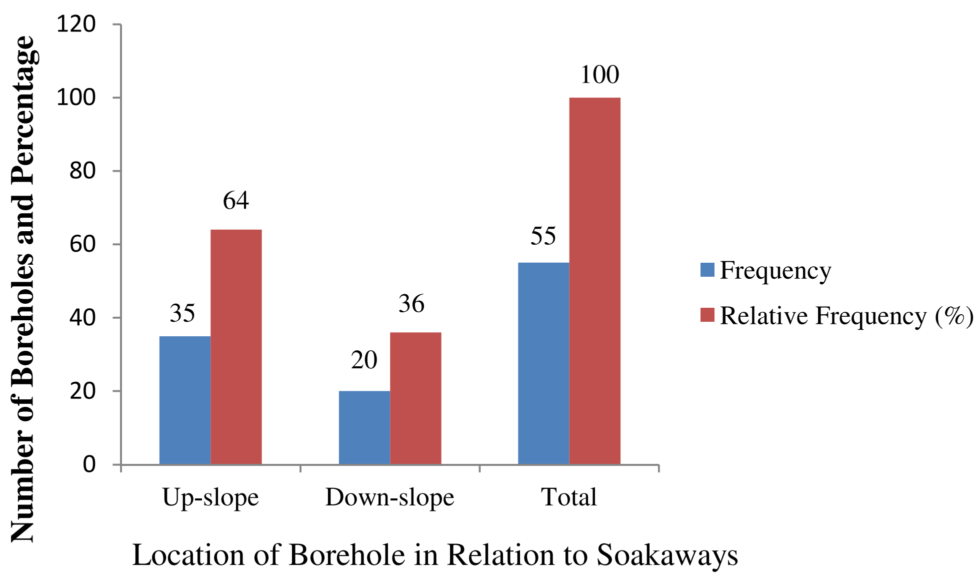
Table 6 shows that the majority of groundwater samples (67.3%) collected were satisfactory in term of total coliform per 100mls. The story was also true for feacal coliform and *E. coli* per 100ml of groundwater as indicated by 67.3% and 89.1% of water samples respectively being satisfactory. Unsatisfactory results were recorded in 32.7% of samples for total and faecal coliforms while *E. coli* was only evident in 10.9% of samples.

4.2 Siting of Boreholes in Relation to Septic Tanks and Soakaways

)

Out of 55 boreholes that were sampled for bacteriological water analysis, results in figure 2 show that 73% were sited 30 metres and more away from the nearest soakaways, while the remaining 27% were sited less than 30 metres away from soakaways.

Figure 3: Location of Boreholes and Soakaways in Relation to Direction of Groundwater Flow



Data on direction of groundwater flow in figure 3 indicate that out of 55 boreholes that were sampled for bacteriological water analysis, 35 were sited up-slope from the nearest soakaways in relation to groundwater flow representing 64%, while 36% were sited down-slope.

4.3 Operation and Maintenance of Septic Tanks and Soakaways

Table 7: Operation and Maintenance of Septic Tanks Systems in Households

Desludging of Septic Tanks	**Frequency**	**Relative Frequency (%)**
Desludged	4	7
Did not Desludge	51	93
Total	**55**	**100**
Effect of Heavy Equipment on Area Surrounding Septic Tank	**Frequency**	**Relative Frequency (%)**
Compacted	2	4
Not compacted	53	96
Total	**55**	**100**

Table 7 shows that out of 55 households visited, 93% of the septic tanks were not desludged in the previous 4 years and only 7% were desludged in the same period. The same table also indicates that the majority (96%) of areas around septic tank systems inspected had no evidence of activities that could lead to compaction of soils around them while 4% had such evidence.

4.4 Associations between Dependent Variable and Independent Variables

4.4.1 Chi-square Test Results

Table 8: Water Quality and Direction of Groundwater Flow

Total Coliform per 100ml of Groundwater	**Location of Borehole in Relation to Soakaway**		**Total**	p-value
	Up-slope	Down-slope		
Satisfactory	29 (52.7%)	8 (14.5%)	37 (67.3%)	**= 0.001**
Unsatisfactory	6 (10.9%)	12 (21.8%)	18 (32.7%)	
Total	**35 (63.6)**	**20 (36.4)**	**55 (100%)**	
Faecal Coliform per 100ml of Groundwater	**Location of Borehole in Relation to Soakaway**		**Total**	p-value
Satisfactory	30 (54.5%)	7 (12.7%)	37 (67.3%)	**< 0.001**
Unsatisfactory	5 (9.1%)	13 (23.6%)	18 (32.7%)	
Total	**35 (63.6%)**	**20 (36.4%)**	**55 (100%)**	

Chi square analysis results in table 8 point out that direction of groundwater flow which potentially has an effect on water quality came out as having an association with total coliform count per 100ml of groundwater with the p-value equal to 0.001. The table also indicates that there was an association between direction of groundwater flow and faecal coliform count per 100ml of groundwater with the p-value being less than 0.001.

Table 9: Water Quality and Distances from Water Sources to Soakaways

Total Coliform per 100ml of Groundwater	Distances between water source and soakaway		Total	p-value
	≥ 30 m	< 30 m		
Satisfactory	25 (45.45%)	12 (21.8%)	**37 (67.3%)**	**0.43**
Unsatisfactory	14 (25.45%)	4 (7.3%)	**18 (32.7%)**	
Total	**39 (70.9%)**	**16 (29.1%)**	**55 (100%)**	
Faecal Coliform per 100ml of Groundwater	**Distances between Water Source and Soakaway**			**p-value**
Satisfactory	27 (49.1%)	10 (18.2%)	**37 (67.3%)**	**0.63**
Unsatisfactory	12 (21.8%)	6 (10.9%)	**18 (32.7%)**	
Total	**39 (70.9%)**	**16 (29.1%)**	**55 (100%)**	

According to Chi square test results (Table 9), there was no relationship between water quality (Total coliform and faecal coliform*)* and the distance from water source to soakaway with p-values equal to 0.43 for total coliform and 0.63 for faecal coliform.

4.4.2 Logistic Regression Analysis Results for Total and Faecal Coliforms

a) Total Coliform

Ideally, direction of groundwater flow and the distance from water source to potential source of pollution determine the location of boreholes and septic tanks in the same area. Table 10 presents results of a logistic regression model that gives in detail the relationship between water quality and factors it may be associated with. Groundwater quality was transformed into a dichotomous variable, i.e. equal to '1' for cases where the total coliform count per 100ml of water was from 0 to 10 and '0' for cases where the count was greater than 10.

Logistic regression in this study recognizes variables that include direction of groundwater flow, distance between water source and soakaway, plot size, water use at household, operation and maintenance of septic tanks/soakaway. These also include age of septic tank and environment around septic tanks.

Table 10 also presents estimates of logistic regression for total coliform count per 100ml of water. Results show that only direction of groundwater flow came out significant at 5% significance level with the p-value of 0.005. The Exp (B) column presents the extent to which raising the corresponding measure by one unit influences the odds ratio. The odds ratio for the direction of groundwater flow was less than 1 (0.118). Distance between water source and soakaway was not significant at 5% significance level and the odds ratio was slightly less than 1 (0.993).

Table 10 Logistic Regression Model for Total Coliform as a Dependent Variable

Variable Description	B	S.E.	Wald	df	Sig.	Exp (B)
Water flow direction,1 = up-slope	-2.133	0.755	7.983	1	0.005	0.118
Distance from water source to soakaway,1= ≥ 30 m and 0 = < 30 m	-0.007	0.034	0.038	1	0.845	0.993
Heavy water use, 1= Evident	-2.39	1.69	1.999	1	0.157	0.092
Plot size,1= high cost	-0.39	0.754	0.267	1	0.605	0.677
Age of septic tank, 1= < 4 years	-0.318	0.908	0.123	1	0.726	0.727
Ever desludged, 1= desludged	0.858	1.362	0.397	1	0.529	2.358
Dampness,1= Evident	-1.278	0.984	1.685	1	0.194	0.279
Heavy equipment parked, 1= Compacted surrounding area	0.847	1.78	0.227	1	0.634	2.334
Environment around septic tank, 1=bare ground	2.818	1.75	2.594	1	0.107	16.748
Constant	1.605	2.664	0.363	1	0.547	4.976

Note: **B**: Logistic regression coefficients **Wald**: Wald statistics (Chi2), **df**: Degree of freedom
S.E: Standard errors **Sig**: Significance **Exp (B)**: Odds ratio.

b) Feacal Coliform

Similar to the case of total coliforms per 100ml of groundwater, water quality was transformed into a dichotomous variable, i.e. equal to '1' for cases where the feacal coliform count per 100ml of water was equal to zero and '0' for cases where the count was 1 or greater. Only direction of groundwater flow was associated with feacal coliform count per 100ml of groundwater at 5% significance level with the p-value of less than 0.001 (Table 11). The odds ratio for the direction of groundwater flow was less than 1 (0.042). Distance between water source and soakaway was not significant at 5% significance level and the odds ratio was slightly greater than 1 (1.062).

Table 11: Logistic Regression Model for Feacal Coliform as a Dependent Variable

Variable Description	B	S.E.	Wald	df	Sig.	Exp (B)
Water flow, 1=up-slope	-3.165	.904	12.261	1	.000	.042
Distance from water source to soakaway,1= ≥ 30 m and 0 = < 30 m	.060	.037	2.640	1	.104	1.062
Heavy water use, 1= Evident	-1.143	1.733	.435	1	.510	.319
Plot size,1= High cost	-.649	.793	.670	1	.413	.523
Age of septic tank, 1= < 4 years	.038	.999	.001	1	.970	1.039
Ever desludged , 1= desludged	.574	1.864	.095	1	.758	1.775
Dampness,1= Present	-.520	.928	.314	1	.575	.595
Heavy equipment parked, 1= Compacted surrounding area	.370	1.887	.039	1	.844	1.448
Environment around septic tank, 1=bare ground	.929	1.778	.273	1	.601	2.533
Constant	21.843	25826.8	.000	1	.999	3064690827

B: Logistic regression coefficients **Wald**: Wald statistics (Chi2), **df**: Degree of freedom
S.E: Standard errors **Sig**: Significance **Exp (B)**: Odds ratio

CHAPTER FIVE

5.0 DISCUSSION OF FINDINGS

The general picture of groundwater bacteriological analysis in this study showed that majority (67.3%) of water samples collected from households in St. Bonaventure were satisfactory, while 32.7% were unsatisfactory. These results indicate that some households use water that was not safe for drinking purposes. According to WHO (2003), drinking water from untreated sources like boreholes is said to be safe when total coliform count is 1 to 10/100 ml and faecal coliform is not present in 100 ml. This, therefore, indicates that about 33% of households in St. Bonaventure used water that did not meet water safety standard.

To get an insight of groundwater safety in St. Bonaventure, relationships between water quality and factors which included distance between water source and soakaway, direction of groundwater flow, plot size, water use at household, operation and maintenance of septic tanks/soakaway, age of septic tank and environment around septic tanks were explored. This was done using Pearson chi-square test (cross tabulations) and logistic regression model; results of the analysis were presented in tables 8 to 11.

5.1 Location of Boreholes in Relation to Direction of Groundwater Flow

Chi-square test results revealed that direction of groundwater flow showed an association with water quality (total coliform and feacal coliform) counts per 100ml of water at p-values equal to 0.001 for total coliform and less than 0.001 for faecal coliform.

To validate results from the simple chi-square test, logistic regression analysis was used. Results further indicated similar outcome for total coliform count per 100ml of water. Table 10 shows that only direction of groundwater flow had association with groundwater quality at 5% significance level with p-value being equal to 0.005 and the odds ratio of 0.118. Since the odds ratio for the direction of groundwater flow was less than 1(0.118), it therefore, meant that up-stream location of borehole(s) was 0.118 times more likely to lead to a reduction in total coliform count per 100ml of groundwater.

Similar results with total coliform were observed from logistic regression analysis for the faecal coliform (Table 11). In this case, direction of groundwater flow came out as having an association with faecal coliform count at 5% significance level with p-value less than 0.001 and the odds ratio of 0.042. This indicates that up-slope location of borehole(s) with respect to soakaway was 0.042 times less likely to lead to presence of feacal coliform in 100ml of groundwater. These results, therefore, showed that if boreholes were located down-slope from the soakaway which is a potential source of contamination, they were more likely to be contaminated with faecal coliform bacteria which indicate faecal pollution.

The outcomes in both total coliform and faecal coliform logistic regression analysis were in line with WHO guidelines of 2001 which require location of boreholes to be up-slope at a minimum distance of 30 metres away from any potential source of pollution. These results, further, showed that if boreholes were located down-slope from the soakaway which is a potential source of contamination, they were more likely to be contaminated with total coliform and faecal coliform bacteria. This could indicate that there was no coordination among partners in water resource management at initial stages of groundwater development in Lusaka District. These results further suggest that residents of St. Bonaventure Township were not guided in order for them to site boreholes and septic tank systems according to guidelines.

5.2 Distances between Boreholes and Soakaways

There was no relationship between water quality (total coliform and faecal coliform) and the distance from borehole to soakaway. Distance from borehole to soakaway was one of the two main determinants of siting water sources and sanitary facilities as indicated in the specific objectives of the study. This could indicate that there were other factors that might have influenced groundwater quality in St. Bonaventure such as geological formation. In support of these findings, Grönwall et al, (2010) state that Lusaka's ground formation is mainly of limestone landscape which is characterized by caves, fissures, rocks and underground streams. This could, therefore, reduce or eliminate the reduction of pollutants that would occur through natural filtration in the soil because groundwater moves rapidly from one point to another.

Logistic regression analysis showed similar results to those in chi-square test between water quality and distance from water source to soakaway. Contrary to UNHCR (2006) guidelines for siting water sources, which set the minimum distance between a borehole and any potentially polluting activity at 30 metres, in this study, the distance between water source and soakaway came out insignificant with p-values equal to 0.104 and 0.845 for faecal coliform and total coliform respectively. The odds ratio for faecal coliform was 1.062 while for total coliform it was 0.993. The two odds ratios indicate that there was no clear association between distance from groundwater source to soakaway and groundwater quality. This could further be attributed to other factors that may influence groundwater quality in Lusaka such as geological formation that is of limestone landscape and characterized by caves, fissures, rocks and underground streams.

According to Grönwall et al. (2010), presence of the said features in the ground means that there are open spaces underground that may allow groundwater to move freely. These characteristics may also enable groundwater to move faster than it could if they were absent. Chidavaenzi et al, (2000) state that fast movement of water in the ground could reduce the contact time between wastewater and predatory microorganisms that are present in the soils around soakaway for them to remove pathogens from wastewater. Consequently, polluted groundwater from soakaways could easily reach drinking water sources before pollutants are filtered out. Rocks in the ground may lead to temporal changes in direction of groundwater flow, a situation which could delay the movement of water. This could make the distance between water source and soakaway insignificant because in some cases distances that seemed to be less than recommended range on the surface, might be within the recommended in the ground. This could be due to temporal diversions of direction of groundwater flow by rocks.

5.3 Other Factors Associated with Groundwater Quality

This study apart from examination of the distance from water source to soakaway and direction of groundwater flow, other factors were also examined and these included; plot size, water usage at household level, operation and maintenance of septic tanks/soakaway, age of septic tank, environment and dampness around septic tanks.

5.3.1 Age of Septic Tanks/soakaways

The age of septic tanks and soakaways may determine the quality of water in the nearby groundwater sources. The age did not come out as a significant factor in this study and the odds ratio of 1.039 indicates that there was no clear association between groundwater quality (faecal coliform bacteria) and the age of soakaway. This is not in conformity to Howard et al, (2006) who state that the biologically active layer that forms in the soils around soakaways appears to take some time to become effective and it works in two key ways. Firstly, the presence of predatory microorganisms within the biologically active layer allows for permanent removal of some pathogens. Secondly, the nature of the layer also reduces the porosity of the soil matrix by clogging the soil pores thereby allowing an increased period for attenuation. This means that boreholes that are near newly constructed soakaways are at risk of faecal coliform contamination.

Total coliform count, however, showed some different association with the age of septic tanks and soakaways. The odds ratio of 0.727 indicates that to some extent, boreholes that were less than 4 years were less likely to get contaminated with total coliform bacteria. This also indicates that there might be something in the ground that needed further investigation.

5.3.2 Storage of Heavy Equipment around Soakaways

Storage of heavy equipment around septic tank systems came out insignificant at 5% significance level with the p-value equal to 0.844 and the odds ratio of 1.448. This indicates that boreholes that were located near soakaways that had heavy equipment stored on them were 1.448 times more likely to be polluted with faecal coliform bacteria. Similar results were observed for total coliform with the p-value being 0.634 and the odds ratio of 2.334. This may have been due to the soils around soakaways being compacted, hence reducing the porosity of the soils around the system. Obropta and Berry (2005) state that driving or parking of vehicles on septic tanks and areas around soakaways would compact the soil, as well as possibly damage the pipes, tanks, or other components of the septic tank system. This may have a negative effect on function of septic tank system as it may lead to overflowing of untreated wastewater. The result in the long run could be pollution of top soils in the immediate surroundings and surface water which may at the end percolate into the ground.

5.3.3 Utilization of Groundwater

The study showed no association between the number of both faecal coliform and total coliform in 100ml of groundwater and large utilization of groundwater at household level (p-values of 0.50 and 0.157 at 5% significance) although this had some protective effect on groundwater quality against both faecal coliform (odds ratio of 0.319) and total coliforms (odds ratio of 0.092) when households used high volumes of water. In this case, households that used large quantities of groundwater were 0.319 times less likely to have faecal coliform contamination of borehole water. Similarly, households that used large volumes of water were 0.092 times less likely to have total coliform contamination of borehole water. This was contrary to Rusinga (2004), who states that abstraction of large volumes of groundwater makes it move towards abstraction points from much further away points. In St. Bonaventure, many households used large volume of water, hence one would expect that households that used such volumes of groundwater, risked their borehole water from getting contaminated with bacteria that might come from soakaway located away from water sources.

5.3.4 Size of Plot on which Households are Located

There was no association between the number of faecal coliform and total coliform in 100ml of groundwater and size of plot on which households were located with p-values of 0.413 and 0.605, respectively, at 5% significance. On the contrary, odds ratios showed some protective effect on groundwater quality against both faecal coliform and total coliform when households were located on bigger plot. In this study, households that were located on bigger plots, their boreholes were 0.523 times less likely to get faecal coliform contamination. Similarly, households that were located on bigger plots, their boreholes were 0.677 times less likely to record total coliform contamination of borehole water. According to Geary and Gardner (1996) on factors related to plot sizes, siting of boreholes and soakaways, the density ranges for septic tanks should be 15 – 25 per square kilometer to ensure protection of groundwater. They, however, state that where groundwater contamination is not an issue, environmentally sustainable plot size allocation should be in the range of 0.4 to 1 hectare i.e. in situations where land values take precedence over the need to protect groundwater quality. It could, therefore, be concluded that optimum land size allocation would be dependent on the subsurface conditions, environmental and public health values of water resources in the area.

5.3.5 Dampness around Septic Tanks

Dampness around septic tanks indicates that the system is not water-tight, hence allowing untreated wastewater into the ground. The results of this study indicated that if dampness was present around septic tank system, the nearest water source was less likely to be contaminated with bacteria

Not in line with these findings, Obropta & Berry (2005) state that a failing septic tank system and its effects on nearby groundwater sources could be noted by presence of dampness over the soakaway and vigorously growing green vegetation is noticed around the area. The effluent may contaminate drinking water source with infectious disease causing organisms and other pollutants. In this study, there was, however, no association between dampness around septic tanks/soakaways and groundwater quality (p-values of 0.575 for faecal coliform and 0.194 for total coliform). These findings could also indicate that there was something wrong underground which may need further studying.

5.4 Limitations of the Study

The study had a number of limitations which included:

- Inadequate local literature to use during study design and report writing. This made the researcher use more information from studies that were conducted internationally.

- During data collection some households were difficult to access because there was need to seek permission from owners using cell phone as they were out for work. This made the research team spend more time at one household in some cases. This increased the cost of the study because more time was required to collect data.

- Use of hired transport to go to all households that were sampled and transporting water samples from study site to Environmental Engineering Laboratory at the University of Zambia proved costly. This meant that the research team was dropped in St. Bonaventure in the morning and picked in the afternoon after a day's work to reduce on cost.

- The study was conducted only in one Township of Lusaka making it difficult to generalize results to the rest of Lusaka

5.5 Conclusion and Recommendations

5.5.1 Conclusion

The study has established that the majority (67.3%) of boreholes in St. Bonaventure had water that was safe for drinking purposes. This situation was, however, still a danger to public health because about 33% of boreholes were contaminated with bacteria that were likely to be of faecal origin. This implies that if the 33% of these households used this water for drinking without any form of treatment, they drank contaminated water putting them at risk of contracting waterborne diseases such as cholera, dysenteries, typhoid and other diarrhoeal diseases.

In this study, distance from borehole to soakaway and location of boreholes in relation to direction of groundwater flow with respect to soakaways were the main factors under investigation. Direction of groundwater flow had an association with groundwater quality (faecal coliform and total coliform with p-values equal to 0.001 and less than 0.001 respectively) at 5% significance level. This study also revealed that there was no relationship between distance from borehole to soakaway and the quality of groundwater in St. Bonaventure. This could be attributed to other factors that might have influenced groundwater quality such as geological formation (Fissures and rocks) that may need further investigation. It could, therefore, be concluded that siting boreholes and septic tank systems in the same area was not suitable for St. Bonaventure Township and Lusaka at large. This was because safety of groundwater could not be guaranteed even when technical and public health requirements were followed during siting of water sources and septic tank systems in some cases especially in terms of distance from water source to soakaway.

5.5.2 Recommendations

- Partners dealing with environmental management issues such as; Zambia Environmental Management Agency, Department of Water Affairs, Geological Department and Lusaka City Council should work together each time projects that involve groundwater development and onsite wastewater treatment are to be implemented.
- Lusaka Water and Sewerage Company should consider provision of piped water and sewerage services to St. Bonaventure in order to protect the community against waterborne diseases
- Lusaka City Council should work with the Geological Department in identifying areas that are suitable to use septic tanks and boreholes on the same piece of land to avoid groundwater pollution
- The Department of Water Affairs should make available groundwater vulnerability maps so that the would-be groundwater developers are aware about the safety of groundwater in Lusaka and the country at large

6.0 REFERENCES

Andrea, N., Museteka, L. and Kringel, R. (2010). ***Hydrochemical Sampling of Groundwater in the Lusaka Urban area and Preliminary Findings Technical Note no. 3.*** Development of a Groundwater Information & Management Program for the Lusaka Groundwater Systems, Republic of Zambia Ministry of Energy and Water Development

ARGOSS (2001). ***Guidelines for Assessing the Risk to Groundwater from On-site Sanitation***. BGS Commissioned Report CR/01/42, BGS, Wallingford.

ARGOSS (2002). ***Assessing Risk to Groundwater from On-site Sanitation: Scientific Review and Case Studies***. BGS Commissioned Report CR/02/079N, BGS, Wallingford.

Bishop, C. (2011). ***In Our Homes, Our Businesses and Our Communities***: The History of Onsite Wastewater Treatment, Shows the Potential for Sustainability, Greensboro, NC, Bord na Móna Environmental Products, US

CSO (2011). ***Census Population and Housing,*** 2010, Lusaka, Zambia.

Chidavaenzi, K., Bradley, M., Jere, M., & Nhandara, C. (2000). ***Pit latrine Effluent Infiltration into Groundwater: The Epworth study***. London: Water sanitation and Health, IWA

Dissanayake, S., Dias, S., Perera M. and Iddamalgoda I., (2004). ***Microbial quality assurance of drinking water supplies through surveillance Proceedings of the Water Professionals Symposium***, (WPS'04). Colombo. Sri Lanka. pp. 141-147.

Geary, P. M. and Gardner, E. A., 1996, 'On-site disposal of effluent', *In Land Management for Urban Development*, Australian Society of Soil Science Inc., Queensland Branch, Invited Lectures, pp. 291-319.

Gideon, T., Lisa, C. and Pannie, E. (2004). ***Groundwater pollution: Are we monitoring appropriate parameters,*** ISSN 0378-4738, Water SA Vol. 30 No. 5 (Special edition) pp.1-2. Available on website http://www.wrc.org.za. Accessed online on the 16th October, 2012

Gilbert, G. P. E. (2008). ***History of onsite wastewater treatment systems, Background Use of onsite Wastewater Treatment s\Systems,*** Continuing Education and Development, Inc. 9 Greyridge Farm Court Stony Point, NY 10980

Goonetilleke, A., Dawes, L. and Biddle, D. (2002). ***Performance evaluation of Septic Tanks in the Gold Coast Region***, GCCC, Gold Coast City, Physical Infrastructure Centre, Queensland University of Technology, Environmental Studies No 8. pp.13-19

Grönwall, J. T, Mulenga, M. and McGranahan, G. (2010). ***Groundwater, self-supply and poor urban dwellers: a review with case studies of Bangalore and Lusaka***. Human Settlements Working Paper 25. London: International Institute for Environment and Development (IIED). Available online: http://pubs.iied.org/10584IIED.html. Accessed online on the 16th October, 2012

GRZ (1995). ***Food and Drugs Act Cap 303 of the Laws of Zambia***. Government Printers, Lusaka, Zambia

Howard, G., Jahnel, J., Frimmel, F. H., McChesney, D., Reed, B., Schijven, J. and Braun, H. E. (2006). ***Human Excreta and Sanitation***: Potential Hazards and Information Needs, Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources. ISBN: 1843390795. Published by IWA Publishing, London, UK

Jurenka B. (2009). Biological: Total Coliform and E. coli Fact Sheet U.S. Department of the Bureau Reclamation

Kawanga, C. O. (2003). ***The impact of urbanization on sanitary conveyances and sewage treatment facilities in the city of Lusaka***, Zambia, Central Statistical Office, Agriculture

Kreissl, J. F. (2000). ***Onsite Wastewater Management at the Start of the New Millennium***. Small Flows Quarterly 1(1):10-11.

Lerner, D. N. and Barrett, M. H. (1996). ***Urban groundwater issues in the United Kingdom***. Hydrogeology J., 4(1), 80-89.

McQuillan, D. (2004). ***Groundwater Quality Impacts from On-site Septic Systems***: Proceedings, National Onsite Wastewater Recycling Association, 13th Annual Conference, Albuquerque, NM, November 7-10, 2004,Field Operations Division, New Mexico Environment Department, 525 Caminodelos Marquez, Suite 1, Santa Fe, NM 87505, 505-827-1400 x 1004,

Natural Environmental Research Council (2011). ***Borehole Location, Construction, Testing and Legal Obligations.*** Georeports, *British Geological Survey Report No: GR_999999/1, P.4*

Obropta, C. and Berry, D. (2005). ***Onsite Wastewater Treatment Systems: The Maintenance and Care of Your Septic System***, Rutgers Cooperative Research & Extension, Agricultural Experiment Station, Rutgers, The State University of New Jersey, New Brunswick

Phil, H. T. D. (2012). ***Proposed Content of Regulations for Operation and Maintenance of Domestic Waste Water Treatment Systems***, Department of the Environment, Community and Local Government, Newtown Road, Wexford.

Reynolds, J. H. and Barrett, M. H. (2003). ***A review of the effects of sewer leakage on groundwater quality***. *JCIWEM*, **17**(1), 34-39.

Rusinga, F. (2004). ***The borehole or well location*****,** Groundwater Protection: Guidelines for Protecting Boreholes and Wells, Department of Water Affairs and Forestry, Directorate: Information Programmes, Private Bag X313, PRETORIA 000, Republic of South Africa.

Scandura, J. E. and Sonsey, M. D. (1997). Viral ***and bacterial contamination of groundwater from onsite treatment systems***. Water Sci. Technol., 35(11-12), 141-146.

Sevebeck, P. K. and Kroehler, J. C. (1992). ***A Guide to Septic Systems and Alternatives***, Virginia Water Resources Research Center, 617 N. Main St. Bonaventure, Blacksburg, VA 24060-3397.

Shadow, W. J. A. (2007). ***A Descriptive Case Study of Teaching and Learning, in an Innovative Middle School Program***, Northern Arizona University

Simms, J. M. S. (2006). ***Local Board of Health Guide to On-Site Wastewater Treatment Systems***. National Association of Local Boards of Health 1840 East Gypsy Lane Road Bowling Green, Ohio 43402.http.www.nalboh.org. Accessed online on the 18th October, 2012

Tole, M. P. ***Pollution of groundwater in the coastal Kwale District, Kenya***, Sustainability of Water Resources under Increasing Uncertainty (Proceedings of the Rabat Symposium S1, April 1997). IAHS Publ. no. 240, 1997

UNESCO (2003). ***Assessment of pollution Status and Vulnerability of Water Supply Aquifers of Africa n cities***, Lusaka Project. http://www.unep.org/groundwaterproject/Archives/Zambia Accessed online on the 19th October, 2012

UNHCR (2006), Practical ***Guide to the Systematic Use of Standards and Indicators in UNHCR Operations.*** www.unhcr.org/statistics/STATISTICS/40eaa9804.pdf. Accessed online on the 29th October, 2012

University of Minnesota (2011). ***Tank Construction Overview,*** Regents of the University of Minnesota, North central United States, U.S. A

Vogel, P. M. (2002). ***How to know if your system is failing: Septic Tank and Drainfield Operation and Maintenance***, Communications and Public Affairs, 416 Culbertson Hall, Montana State University–Bozeman, Bozeman MT 59717;

Vogel, P. M. (2005). ***How septic system works: Septic Tank and Drainfield Operation and Maintenance***, Communications and Public Affairs, 416 Culbertson Hall, Montana State University–Bozeman, Bozeman MT 59717

WHO (2001). ***Water Quality: Guidelines, Standards and Health***. Published by IWA Publishing, London, UK. ISBN: 1 900222 28 0

WHO (2003). Guidelines for Drinking Water Quality 3rd Edn. WHO, Geneva.

WHO (2006). ***Protecting Groundwater for Health***: ***Managing the Quality of Drinking-water Sources***. ISBN: 1843390795. IWA Publishing, London, UK.

7.0 APPENDICES

7.1 Information Sheet

EFFECT OF SITING BOREHOLES AND SEPTIC TANKS ON GROUNDWATER QUALITY IN ST. BONAVENTURE TOWNSHIP OF LUSAKA DISTRICT

Introduction

I Luke John Banda, a student of Masters Degree in Public Health at the University of Zambia is requesting for your participation in the study mentioned above. The essence of the study is to assess the effect of siting boreholes and septic tanks on groundwater quality. Before you decide whether or not to participate in the study, I would like to explain to you the purpose of study and what is expected of you. Your participation in this study is entirely voluntary and you are, therefore, under no obligation to participate. If you agree to participate, you will be asked to sign this consent in front of someone. Agreement to participate will not result in any immediate benefit.

Purpose of the Study

The study will assess how siting boreholes and septic tanks affect groundwater quality in St. Bonaventure Township. The information obtained will help Lusaka City Council, Lusaka Water and Sewerage Company and other stakeholders to take measures in planning the provision of safe water supply and sewage treatment services.

Procedures

The study will involve sampling of water from boreholes and taking it to Public Health Laboratory at the University Teaching Hospital for analysis. Measurements of distances between boreholes and soakaways will be taken using a 50 meter tape measure and information on direction of flow of groundwater around St. Bonaventure area will be collected from the Department of Water Affairs. Inspection of septic tanks and soakaways will be conducted to assess the state of repair and general hygiene and members of households will be asked to state when their septic tanks were last pumped out.

Risk Factors and Discomforts

There is no risk involved in the study though part of your time on your busy schedule will be utilized to facilitate the collection of water samples. If you feel uncomfortable in the process you have the right to withdraw from the exercise.

Benefits

There may be no direct benefit for you by participating in this study, but the information which will be obtained will help policy makers formulate policies to curb the risk of contamination of groundwater due to the combination of using boreholes and septic tanks in the same area. No monitory favours will be given in exchange for information obtained.

Confidentiality

The research record and information will be treated as confidential to the extent permitted by law. All information that will be collected will be kept under lock and key. Further, your name will not be entered or recorded anywhere; boreholes and septic tanks will be identified by numbers. No such information will be released without your permission but results of water analysis of your borehole will be given to you in case it is contaminated so that corrective measures can be advised.

The UNZA Biomedical Research Ethics Committee or the School of Medicine may review your record again but this will be done with confidentiality.

7.2 Informed Consent Form

EFFECT OF SITING BOREHOLES AND SEPTIC TANKS ON GROUNDWATER QUALITY IN ST. BONAVENTURE TOWNSHIP OF LUSAKA DISTRICT

Sponsor: The University of Zambia
Name of Student: Luke John Banda

The purpose of this study has been explained to me and I understand the purpose, benefits, risks and discomfort, and confidentiality of the study.

I further understand that: if I agree to take part in this study I can withdraw at any time without having to give an explanation and that taking part in this study is purely voluntary.

I ____(Names)
Agree to take part in this study
Signed:_______________________Date:________________(Participant)
Participant's signature or thumb print.

Signed:_______________________Date:_________________(Student)

Signed:_______________________Date:_________________(Witness)

Student's Contact details

University of Zambia
School of Medicine,
Department of Community Medicine
P.O Box 50110
Cell No. 0977270214

If you have any questions, concerns and clarifications, contact the University of Zambia Research Ethics Committee on the following addresses:

The University of Zambia
Biomedical Research Ethics Committee
Telephone: 256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@zamtel.zm

7.3 Data Collection Tools

7.3a Sampling Form

REPUBLIC OF ZAMBIA

MINISTRY OF HEALTH
SAMPLING FORM
FOOD AND DRUGS ACT CAP 303 OF THE LAWS OF ZAMBIA

<table>
<tr><td colspan="2">1. Sample No.</td><td colspan="2">2. Date Collected:</td></tr>
<tr><td colspan="4">3. (a) Product name and description:…………………………………………………………
(b) Method of collection: ……………………………………………………………….
(c) Collector’s identity on package and seal: …………………………………………...</td></tr>
<tr><td colspan="4">4. Reasons for collection:</td></tr>
<tr><td colspan="2">5. Manufacturer:</td><td colspan="2">6. Dealer:</td></tr>
<tr><td colspan="2">7. Size of lot sampled:</td><td colspan="2">8. Date dispatched:</td></tr>
<tr><td>9. Delivered to:</td><td colspan="2">10. Date:</td><td>11. Laboratory:</td></tr>
<tr><td rowspan="2">12. Records obtained</td><td colspan="2">(a) Invoice No. and date</td><td>(b) Shipping record and date</td></tr>
<tr><td colspan="3">(c) Other documents:</td></tr>
<tr><td colspan="4">13. Remarks:
(a) Distance between water source and soakaway: (...............Metres)
(b) Location of water source in relation to direction of groundwater flow and nearest soakaway:
(i) Up-slope (ii) Down-slope
(c) Type of pump : (i) Motorized (ii) Manually Operated
(d) Presence of heavy use of water: (i) Yes (ii) No</td></tr>
<tr><td colspan="2">14. Sample cost:</td><td colspan="2">15. Collector (Print Name & Signature)</td></tr>
</table>

7.3b: Inspection Guide

EFFECT OF SITING BOREHOLES AND SEPTIC TANKS ON GROUNDWATER QUALITY IN ST. BONAVENTURE TOWNSHIP OF LUSAKA DISTRICT

Date: ………………………

Septic tank/soakaway ID No: ……………………. Nearest Borehole ID No: ……………………

Evaluation of Adequacy of Operation and Maintenance of Septic Tanks and Soakaways

(Please circle)

1. Find out when the septic tank at the household was constructed
   a) A year ago
   b) 2-4 years ago
   c) More than 4 years ago
   d) Not sure

2. Find out the last time the septic tank was pumped
   a) Less than 6 months ago
   b) A year ago
   c) 2-3 years ago
   d) More than 3 years ago
   e) Not sure

3. The immediate environment around the septic system; what type of finish is it?
   a) Bare ground
   b) Grass loan
   c) Paved
   d) Other (specify): ……………………………………………………………………….

4. Any sign of dampness/accumulation of water around the septic tank or soakaway
   a) Yes b) No

5. Any accumulation of solid matter in the soakaway:

   a) Yes b) No

6. Presence of fast growing vegetation around septic tank or soakaway

   a) Yes b) No

7. Any car parking around the septic system:

   a) Yes b) No

8. Any storage of heavy equipment around the septic tank or soakaway:

   a) Yes b) No

9. Any other activities done on and around septic system not related to its maintenance or operation: ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

7.3c List of Supplies

- Cold boxes
- Water Sampling Bottles
- Ice Packs
- Methylated Spirit
- 100 Meter Tape Measure
- Match Boxes
- Tongues

7.4 Permission Letters

7.4.1 Permission Letter from the Assistant Dean Postgraduate Studies

THE UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE

Telephone: 252641
Telegram: UNZA, Lusaka
Telex: UNZALU ZA 44370
Email: selestinenzala@yahoo.com

P.O. Box 50110
Lusaka, Zambia

==

26th November, 2012

Mr Luke John Banda
Department of Community Medicine
School of Medicine
LUSAKA

Dear Mr Banda,

RE: GRADUATES PROPOSAL PRESENTATION FORUM (GPPF)

Having assessed your dissertation entitled **"Effect of sitting of Boreholes and Septic tanks on groundwater quality in Saint Bonaventure Township of Lusaka District".** We are satisfied that all the corrections to your research proposal have been done. The proposal meets the standard as laid down by the Board of Graduate Studies.

You can proceed and present to the Research Ethics.

Yours faithfully,

Dr. S. H. Nzala
ASSISTANT DEAN, POSTGRADUATE

CC: HOD – Community Medicine

UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE
26 NOV 2012
ASSISTANT DEAN (PG)
P.O. BOX 50110, LUSAKA

7.4.2 Letter of Authority from Lusaka City Council to Conduct the Study

LUSAKA CITY COUNCIL

OFFICE OF THE TOWN CLERK

P.O BOX 30077
CIVIC CENTRE
LUSAKA, ZAMBIA, 10101

www.lcc.gov.zm

TELEPHONE: 01 252997
TELEFAX: 01 252141
lusakacitycouncil@mlgh.gov.zm

Our Ref: PHD/6/9/3

28th November, 2012.

Mr Banda,

UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE
30 NOV 2012
RECEIVED
ASSISTANT DEAN (PG)

Assistant Dean, Postgraduate,
University of Zambia,
School of Medicine,
P.O Box 50110,
Lusaka.

Dear Sir,

RE: REQUEST TO CONDUCT A STUDY IN ST BONAVENTURE TOWNSHIP – MR LUKE JOHN BANDA

Reference is made to your letter dated 26th November 2012 with the above captioned subject.

We wish to advise that we have no objection to your request. Let the student get in touch with the Director of Public Health for further guidance.

Yours faithfully,

Andrew Mwanakulanga
Town Clerk

C.c The Director of Public Health - LCC

6.4.3 **The UNZA Biomedical Research Ethics Committee Approval Letter**

6.4.4 Water Analysis Laboratory Results

THE UNIVERSITY OF ZAMBIA
School of Engineering
Department of Civil and Environmental Engineering
Environmental Engineering Laboratory
P.O.Box 32379, Lusaka
Direct Tel/Fax: 260-1-290598/962

BACTERIOLOGICAL EXAMINATION OF WATER

Reference: **A12064**
Address: **Mr. Luke John Banda**
UNZA Ridgeway
Lusaka

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
25 APR 2013
DEPT. OF CIVIL ENGINEERING
P.O. BOX 32379 LUSAKA

Report Date: 25.04.2013

Sample ID	Description	Sampling Date	Total coliforms (#/100ml)	Feacal coliforms (#/100ml)	E.coli (#/100ml)
01/284/13	Untreated Borehole	14.04.013	0	0	0
02/230	Untreated Borehole	14.04.013	4	0	0
03/225	Untreated Borehole	14.04.013	0	0	0
04/221	Untreated Borehole	14.04.013	5	0	0
05/189	Untreated Borehole	14.04.013	0	0	0
06/210	Untreated Borehole	14.04.013	31	7	2
07/213	Untreated Borehole	15.04.013	9	1	0
08/238	Untreated Borehole	15.04.013	15	0	0
09/170	Untreated Borehole	15.04.013	39	0	0
10/186	Untreated Borehole	15.04.013	6	1	0
11/177	Untreated Borehole	15.04.013	0	0	0
12/257	Untreated Borehole	15.04.013	0	0	0
13/245	Untreated Borehole	15.04.013	0	0	0
14/267	Untreated Borehole	15.04.013	TNTC	TNTC	82
15/274	Untreated Borehole	15.04.013	0	0	0
16/312	Untreated Borehole	15.04.013	40	20	7
17/283	Untreated Borehole	15.04.013	0	0	0
18/291	Untreated Borehole	18.04.013	25	18	0
19/299	Untreated Borehole	18.04.013	TNTC	TNTC	0
20/342	Untreated Borehole	18.04.013	0	0	0
21/305	Untreated Borehole	18.04.013	0	0	0
22/324	Untreated Borehole	18.04.013	0	0	0
23/327	Untreated Borehole	18.04.013	28	5	0
24/350	Untreated Borehole	18.04.013	98	28	12
25/359	Untreated Borehole	18.04.013	0	0	0
26/366	Untreated Borehole	18.04.013	35	28	0
27/370	Untreated Borehole	18.04.013	0	0	0
28/397	Untreated Borehole	18.04.013	0	0	0

29/377	Untreated Borehole	18.04.013	0	0	0
30/417	Untreated Borehole	19.04.013	12	8	0
31/421	Untreated Borehole	19.04.013	94	75	2
32/425	Untreated Borehole	19.04.013	29	3	0
33/405	Untreated Borehole	19.04.013	34	20	0
34/407	Untreated Borehole	19.04.013	0	0	0
35/460	Untreated Borehole	19.04.013	0	0	0
36/463	Untreated Borehole	19.04.013	0	0	0
37/498	Untreated Borehole	19.04.013	0	0	0
38/483	Untreated Borehole	19.04.013	0	0	0
39/488	Untreated Borehole	19.04.013	0	0	0
40/476	Untreated Borehole	19.04.013	0	0	0
41/383	Untreated Borehole	19.04.013	0	0	0
42/506	Untreated Borehole	19.04.013	0	0	0
43/458	Untreated Borehole	19.04.013	0	0	0
44/149	Untreated Borehole	20.04.013	0	0	0
45/134	Untreated Borehole	20.04.013	0	0	0
46/119	Untreated Borehole	20.04.013	77	28	7
47/102	Untreated Borehole	20.04.013	0	0	0
48/111	Untreated Borehole	20.04.013	15	2	0
49/99	Untreated Borehole	20.04.013	0	0	0
50/521	Untreated Borehole	20.04.013	13	4	0
51/547	Untreated Borehole	20.04.013	66	4	0
52/530	Untreated Borehole	20.04.013	0	0	0
53/534	Untreated Borehole	20.04.013	0	0	0
54/538	Untreated Borehole	20.04.013	0	0	0
55/552	Untreated Borehole	20.04.013	0	0	0

Tests Carried out in conformity with " Standards Methods For The Examination of Water And Wastewater APHA, 1998"

J. Kabika
Coordinator