MITIGATING THE EFFECTS OF SEPTIC TANK EFFLUENTS FROM HOUSEHOLDS ON GROUNDWATER QUALITY: A CASE OF MEANWOOD-KWAMWENA, LUSAKA

by

Francis Dabwiso Daka

A dissertation submitted in partial fulfillment of the requirements of the degree of Master of Engineering (M.Eng) in Project Management.

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DECLARATION

I, **Francis Dabwiso Daka** do hereby declare that the contents of the dissertation being submitted herein are my original work and they have not been previously submitted to any University for the award of a degree or any other qualification.

Signature………………………………………. Date…………………………………

CERTIFICATE OF APPROVAL

This dissertation submitted by, **Francis Dabwiso Daka** is approved as fulfilling the requirements for the award of the degree of Master of Engineering in Project Management at the University of Zambia.

Examiner …………………..………… **Signature**…………………. **Date** …………………

Examiner ………………………….**Signature**……………………..**Date**........................

Examiner………………………… **Signature**…………………….....**Date** ………………

Chairman Board of Examiners…………...**Signature**………………. **Date** …………………

Supervisor…………………………………**Signature**…………………**Date**……………………

ABSTRACT

Disposal of household effluent by septic tank systems is the most common method carried out by people that live in Lusaka's forthcoming settlements, in Zambia. Furthermore, water for domestic use is primarily supplied from private boreholes because of the absence of piped water; and lack of sewerage systems in the area is also an issue of concern to this problem.

The Research was descriptive in nature and used mixed methods (quantitative and qualitative) for data collection. Then field observations were done in Meanwood-Kwamwena area followed by structured interviews with key stakeholders who were selected purposely based on their knowledge about septic tanks.

The sample size for the study was 13 respondents. This was based on the consideration of a worst case scenario of 50 percent of households not complying with standards for mitigating groundwater contamination and 95 percent confidence level with 5 percent margin of error and a confidence interval of 27 percent. The sample size was determined using a website based sample size calculator from the website of The Survey System.

Questionnaires and Personal interviews were used in this study. Also used was the 50m Tape measure and dip stick for measuring depth of the septic tank.GIS data was also obtained by GPS map 60 instrument.

A sample size of 13 was drawn from the total population of 7100 that the researcher used for the purpose of the study which represented the total population. These were sampled randomly. In the study area, 38.5 percent of boreholes were found to be contaminated with feacal coliforms and total coliforms and most of these were at a lower elevation. Distances between borehole and septic tanks were limited by plot sizes and averaged about 50 percent less than the minimum required distance by WHO.

A set baseline here was one where pollutants were within WHO standards. The findings also provided a basis for the selection of specific mitigation measures which would be cost effective. Contamination of groundwater quality calls for rigorous management measures to be put in place by relevant Government authorities to safeguard human health and the environment.

Keywords: septic tank, effluent, contamination, groundwater quality, pollutants.

DEDICATION

This work is dedicated to my late parents Mr. Francis T. Daka and Mrs. Agness Patience Uteka Daka, my dearest wife Constance Chinyemba Daka, my sisters Christine Daka, Maureen Daka Sakala, my children Tendai Daka, Francis Daka Jr., and Michael Chikondi Daka who have, for their love, stood by my side and unceasingly shared with me the challenges and hardships during my studies at the University of Zambia. I genuinely thank them all for their unwavering support and understanding when I could not be fully available for them during my studies.

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ABBREVIATIONS

ADB	African Development Bank
CBO	Community Based Organizations
CEH	Centre for Environmental Health
CSO	Central Statistics Office
DHID	Department of Housing and Infrastructure Development
DTF	Devolution Trust Fund
E. Coli	Echeria Coli
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ERB	Energy Regulation Board
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GIS	Geographic Information System
GRZ	Government of the Republic of Zambia
GTZ	German Agency for Technical Cooperation
ICT	Information Communication Technology
IDA	International Development Association
IEC	International, Education and Communication
LAs	Local Authorities
LCBD	Lusaka Central Business District
LCC	Lusaka City Council
LSKA	Lusaka Karst Aquifer
LWSC	Lusaka Water and Sewerage Company
LWSSD	Lusaka Water Supply, Sanitation and Drainage
MCA	Millenium Challenge Account
MCA-Z	Millennium Challenge Account-Zambia
MCC	Millennium Challenge Compact
ME	Ministry of Energy

MFNP	Ministry of Finance and National Planning
MLG	Ministry of Local Government
MOH	Ministry of Health
MWDSEP	Ministry of Water Development, Sanitation and Environmental Protection
NBR	National Building Regulations
NBSAP	National Biological Diversity Strategy and Action Plan
NCC	Ndola City Council
NCS	National Conservation Strategy
NEAP	National Environmental Action Plan
NERC	National Environmental Research Council
NGO	Non Governmental Organizations
NHC	Neighborhood Health Committee
NPE	National Policy on Environment
NWASCO	National Water Supply and Sanitation Council
NWP	National Water Policy
OWTS	On-site Wastewater Treatment System
pH	pondus Hydrogenium
SADC	Southern African Development Community
SEPA	Scottish Environment Protection Agency
SNDP	Sixth National Development Plan
ST-SAS	Septic Tank-Soil Absorption System
TNTC	Too Numerous to Count
UN/DESA	United Nation Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNEP	Unite Nations Environmental Program
UNESCO	United Nations Educational, scientific and cultural organization
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations International Children’s Emergency Fund
UNIDO	United Nations Industrial Development Organization

US	United States
US EPA	United States Environmental Protection agency
WARMA	Water Resource Management Authority
WASAZA	Water and Sanitation Association of Zambia
WDC	Waterborne Disease Centre
WEC	World Energy council
WHO	World Health Organization
WSP	Water and Sanitation Program
WSS	Water Supply and Sanitation
ZANAMA	Zambia National Marketeers Association
ZEMA	Zambia Environmental Management Agency

NOMENCLATURE

N	Number of occupants per household
V	Volume of septic tank system (m^3)
h	Height of septic tank (m)
l	Length of septic tank (m)
Q	Estimated sewage flow per day (m^3/day)
w	Septic tank width (m)

CHAPTER 1 INTRODUCTION

1.1 Overview

In an urban set up where practicing of on-site effluent disposal systems using Septic Tanks have been found to create a risk of contamination to groundwater, hence the need for mitigation measures to reduce contamination of groundwater (Mumma et al., 2011). Currently, many forthcoming areas in Lusaka depend on groundwater abstracted from boreholes for domestic use which includes drinking (Banda, 2013). Thus, there is need to assess the impact that septic tanks have on groundwater quality on which these specified populations depend. This will help in sensitizing all the stakeholders concerned on the need to protect groundwater quality and possible mitigation measures that could be employed (ADB, 2015a).

The water supply and sanitation sector in Zambia has not been developed considerably as the sector is generally under financed and staffed and thus, unable to meet its service delivery responsibilities. Local authorities are responsible for providing clean water and sewarage services, and that delivery effectiveness depends on both technical competence and cost recovery as well as financial viability (MCC, 2013).

Subsurface sewage disposal systems are the largest sources of waste water to the ground and are the most frequently reported causes of groundwater contamination. The likelihood of groundwater contamination by these systems is greatest where septic systems are closely spaced as in subdivided tracts in suburban areas and in areas where the bedrock is covered by little or no soil (USEPA, 2017).

Septic tanks and soakaways are suitable means for On-site Wastewater Treatment System (OWTS) when lot size and subsurface conditions offer adequate natural means of reducing pathogenic organisms and organic matter (Banda, 2013). Septic tank effluent can also be reduced through evapo-transpiration and also by geological barriers as it is seeping into the aquifer. Groundwater contamination has occurred in many settlements which are utilizing the OWTS because of the discharge of effluent which often percolates into the subsurface and contaminates the aquifer where the boreholes tap from (Ibid).

1.2 Mitigating effects of septic tank effluents on groundwater quality

Lusaka is grappling with a sanitation crisis that claims lives through annual outbreaks of cholera, typhoid and dysentery and causes severe environmental pollution. An estimated 70 percent of Lusaka's urban residents live in peri-urban areas, which are relatively high-density, unplanned and largely comprised of low income residents (ADB, 2015a). About 90 percent of peri-urban areas rely on pit latrines, which are unimproved, that is, they do not conform to the design specifications and standards. The remaining 10 percent use sewers, septic tanks or defecate in the open space (Ibid). It is further estimated that 14 percent of households in Lusaka is connected to piped sewerage system and the remainder depends on on-site solutions such as pit latrines, septic tanks and open defecation. Some examples of areas where septic tanks are used for sewage disposal in Lusaka are mass media Complex, Chalala and Meanwood, the study site (MLGH, 2015a) .

The hydro-geological features of the City of Lusaka and surrounding areas are comprised of an aquifer having a unique karst, cavities and fissures formed in soluble carbonate rocks (FAO, 2016). In addition, 57 percent of Lusaka's water supply is abstracted from shallow groundwater sources which are prone to contamination through fissures in the underlying rock (ADB, 2015a). These fissures manifest themselves on the surface as pits and caves. The presence of these fissures in marbles makes them vulnerable and susceptible to groundwater contamination (MLGH, 2015a).

Furthermore, peri-urban areas are made up of unplanned settlements and are high density areas. Sanitation facilities are mostly pit latrines, and septic tank systems are rare. Some families have no latrines at all and depend on shared latrines or resort to open defecation. The peri-urban areas are prone to diarrheal diseases linked to poor sanitation. About 60 percent of the population lives under the poverty datum line and unemployment is about 31 percent. Lack of access to water and sanitation brings about lack of personal safety in sanitation (ADB, 2015a).

A typical 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 groundwater aquifer. This process, however, depends on certain circumstances such as geological and climatic conditions. The release of pollutants into the aquifer can result, if a septic system is improperly sited and constructed (Dutches County, 2016).

The cost of providing conventional sewage collection and treatment facilities is usually high and not economically feasible, especially in sparsely populated areas. In these circumstances, on-site treatment of sewage becomes an alternative as they have become a common feature in 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 less complicated technology of these systems, failure is common and it can lead to significant adverse impacts. It is, therefore, imperative that strict compliance criteria and management practices are adopted. This is in regards to wastewater treatment with reliable strategies taken to ensure that the householder adheres to the set standards by relevant authorities (Kim et al., 2016).

1.3 Problem statement

The city of Lusaka has and continues to experience rapid development of new housing settlements to cater for the ever growing population. The key challenge is the non existence of appropriate sewerage infrastructure which if available would be used to convey the household sewage to a suitable treatment facility. Meanwood-Kwamwena, a new housing area in Lusaka is no exception. Residents have to rely on on-site sewage collection and treatment facilities which results in sewage effluent percolating into the aquifer. The overall effects of this practice are not fully comprehended. Therefore, the problem statement of this research can be summarized as follows: - ***"continuous effluent discharge into the aquifer without analyzing the impacts can affect the health status of residents who also draw their portable water needs from the same aquifer".*** Hence this research was undertaken to mitigate this problem.

1.3.1 Research questions to be answered

The research questions to be answered in this study were as follows:

1. What are the effects or impacts of septic tank effluents on groundwater quality?
2. What policies exist for mitigating the effects of septic tank effluents from households on groundwater?
3. What measures need to be put in place to investigate the effects of septic tank effluents?

1.3.2 Objectives of the study

1.3.2.1 General Objectives

a) This research provides information upon which the design of mitigation measures can be based.

1.3.2.2 Specific Objectives:

a) To investigate the effects of septic tank effluents on groundwater quality.
b) To asses existing policies for mitigating the effects of septic tank effluents from households on groundwater quality.
c) To design a framework for mitigating the effects of septic tank effluents.

1.4 Contribution to the sector

This research study contributes to the sector's knowledge base in two ways:

i. Assist policy makers by providing information on mitigation of septic tank effluents from contaminating groundwater.
ii. The findings will also help regulators and authorities on ensuring that groundwater is not contaminated.

1.5 Justification of the study

Whenever settlements are created, there are common challenges which come up such as inadequate water supply, deteriorated environmental conditions characterized by poor sanitation and poor drainage. Thus, groundwater quality is likely to deteriorate with the increasing population. This leads to outbreaks of diseases such as diarrhoea, typhoid and cholera.

Furthermore, there were no known similar studies that had been carried out before in the study area at the time of carrying out the research. This was because borehole water was perceived to be safe without relating it to use of septic tank systems in the same area. Other studies which were conducted focused on contamination of wells with respect to pit latrines in slums and also on the need for Lusaka residents to use borehole water as a safe alternative source of drinking water because LWSC was unable to meet the demand. Also, other studies conducted in low density areas of Lusaka showed high levels of bacterial contamination which was attributed to the fact that the City of Lusaka is built on a mable which is comprised of caves and fissures formed in soluble carbonate rocks (GRZ, 2009). These parameters reduce the ability of the aquifer to naturally reduce the contaminants in the water that flows through it (Cheremisinoff, 1997). Hence, there is going to be bacterial contamination of groundwater within the catchment area of Lusaka and Meanwood-kwamwena is going to be affected since it is within the location of Lusaka, hence the need for conducting this study (ADB, 2015a).

This study which focussed on mitigating groundwater contamination was designed to assess the various factors that could contribute to the contamination of groundwater such as siting boreholes and septic tanks in the same plot area, capacity of septic tanks e.t.c., in Lusaka's Meanwood area. This is important because Lusaka is expanding at a fast rate and the findings will help the stakeholders concerned to put corrective measures to prevent groundwater contamination.

This study has a project management perspective and bridges the gap with scientificific methods of mitigation measures of groundwater contamination.Studies that have been conducted in the past are mainly on public health, and environmental and water engineering point of view with no project management perspective. Hence this study provides a clear link to project management in general.

The findings of the study will help in sensitizing the stakeholders concerned with aspects of mitigating septic tank wastes from contaminating groundwater. The suggested recommendations will greatly benefit the residents and the country at large by minimizing groundwater contamination.

However, World Bank (2015) reported that there is inadequate enforcement of guidelines to guide housing developers so that effluent from septic tank system does not pollute groundwater. This was also attributed to limited information on the effects of septic tank systems on groundwater quality. Consequently, Lusaka might experience outbreaks of preventable water borne diseases due to contamination of groundwater which is perceived to be the safest drinking water source (World Bank, 2015). According to WHO (2003), 80 percent of sicknesses and deaths among children in the world are caused by unsafe drinking water. It also stated that on average, every 8 seconds in the world, a child dies because of drinking contaminated water and Zambia is not an exception. Therefore, 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 have a continued effect (WHO, 2003).

1.6 Scope of Work

The research was restricted to Meanwood-Kwamwena which is relatively a new development area on the northern part of Lusaka. The area has no existing sewerage network and residents rely on onsite sanitation solutions. The research would cover the following;

- Reviewing of literature in detail with respect to groundwater contamination from septic tanks.
- Then field observations in Meanwood-Kwamwena area followed by structured interviews with stakeholders.
- Investigating the effects of septic tank effluents on household water quality which would involve the knowledge of: 1) Approved septic tank design standards in Zambia; 2) water quality standards; 3) distance from water source (borehole) to soakaway; 4) maintenance of septic tanks; 5) housing plot size.
- Determination of septic tank volumes, which are to be compared with standard volumes as provided by NCC.
- Measurement of distances between sources of water (borehole) and septic tank systems so as to compare with the standard distance as provided by WHO.
- Water samples to be collected from the sampled household and testing for bacteriological contamination.
- Data analysis on the impact of onsite sanitation systems on groundwater quality.
- Reviewing the existing policies and regulations for mitigating impacts of groundwater quality.
- Then the framework for mitigating the effects of septic tank effluents on groundwater quality to be designed.

1.7 Structure of the disertation

In addition to this introductory chapter, this disertation also includes chapters 2, 3, 4, 5 and 6. Chapter 2 reviews the literature on groundwater contamination with respect to septic tank effluents. Thereafter, Chapter 3 presents a detailed methodology. Then, Chapter 4 presents the results, whereas Chapter 5 presents the discussion and Chapter 6 presents the conclusion and recommendations.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This Chapter presents the Literature Review in connection with sanitation challenges arising from groundwater contamination caused by effluents from septic tanks. It also reviews literature on septic tanks and parameters affecting groundwater quality. It also reviews the legal and regulatory framework and existing policies in the water and sanitation sector.

2.2 Overview

Septic tanks sometimes referred to as conventional septic tanks are onsite systems used in many parts of the world for domestic wastewater treatment (Busan et al., 2015). Their use is not only limited to single households, but also to moderately small institutions or housing compounds of up to 500 people (Eko, 2013). High use of septic tanks in Sub-Saharan Africa stems from its simplicity to manage and comparatively low construction costs (Sibooli, 2013).

2.3 Problems associated with poor sanitation in Zambia

WSP (2012) reported that Zambia loses 1.3 percent of Gross Domestic Product (GDP) due to poor sanitation, which results in illnessess and premature deaths. In addition, the economic burden of inadequate sanitation falls mostly on the poor who ussually have inadequate sanitation facilities (WSP, 2012).

Furthermore, Lusaka is suffering from a sanitation crisis that claims lives through annual outbreaks of cholera, typhoid and dysentery. About 70 percent of Lusaka's urban residents live in peri-urban areas, which are comparatively high density, unplanned and comprised mainly of low income residents. Additionally, an estimated 90 percent peri-urban areas rely on pit latrines and the remainining 10 percent use septic tanks, sewer systems or defecate in the open area (ADB, 2015a).

In addition, 57 percent of Lusaka's water supply comes from groundwater sources which are prone to contamination through fissures in the underlying rock (Ibid). Moreover, susceptible areas coincide with low-income neighbourhoods, making OWTS an attractive sanitation option in these areas. Despite widespread consensus regarding the need to construct sewers, the city has been reluctant to shoulder investment costs which are relatively high as compared to the OWTS (Ibid).

2.4 Septic tanks and aqua privies

A septic tank is a sewage treatment system comprised of the tank and soakaway. The wastewater generated by the household is disposed off in the septic tank where it is retained for one to three days. During retention, the treatment process commernces where the solid substance settles at the bottom to form sludge, then the liquid effluent passes on to the secondary disposal system known as soakaway where further treatment takes place. A septic tank is comprised of an inlet and outlet and is usually constructed with two compartments so as to improve the efficiency of sewage treatment. The size is also important as it provides an optimal retention time for the treatment of sewage. The sewage is broken down into heavy solids also known as sludge which settles at the bottom of the tank where it accumulates and increases in thickness. The ligher solid materials float to the surface to form scum (Wickell, 2018).

The digestion process which takes place in the septic tank produces some gases which rise to the surface to join the scum and with time, the scum layer thickens and the surface hardens and can shut down the septic tank, hence the need for pumping out periodically (Moving.com, 2018).

Septic tanks are commonly used for the treatment of wastewater from households and may also be appropriate to situations where the volume of wastewater produced is too large for disposal in pit latrines or where conventional sewerage is not economical. The Septic tank systems are reliable and odour-free systems. However, they require a reliable water supply, maintenance of waste pipe systems and regular emptying. The major disadvantage is that groundwater pollution from septic tank drainage fields is more likely to occur than from pit latrines because the volume of liquid infiltrated is much greater (Health and Social Services, 2017).

The aqua privy is similar to the septic tank, the difference being that the tank is located just below or adjacent to the toilet.The water needed for flushing is less as compared to septic tank systems. The cost of construction is low as it utilizes less space and sub-surface drainage for soaking away the effluent is reduced. Furthermore, the quantities of waste pipes used are minimized as they connect directly into the pit. Blockages are less likely and solid anal cleansing material may be used. An aqua-privy is therefore an ideal solution where pit latrines are considered unacceptable. The tank of the aqua privy must be watertight to maintain a constant liquid level.The Advantages of aqua privy are that the latrines are easy to clean, and it is more efficient to empty one big tank than individual pourflush latrines. They are cheaper and require less maintenance than septic tank systems. The disadvantages are that they are difficult to construct, and need a reliable water supply.The tank must have an external access cover and vehicular access, as it will need to be emptied. The site for the tank should not be waterlogged or prone to flooding (Reed, 2011).

Wastes generated from the household flows to the septic tank where it is partially treated. After one to three days of retention, partially-treated effluent flows to a soakaway, where the wastewater is allowed to soak into the soil where the liquid is disposed off and naturally treated at the same time (Ibid).

2.5 Construction, operation and maintenance of septic tanks

Septic tanks are generally constructed from concrete, polyethelyn (plastic) or fibre glass materials. Traditionally septic tanks are made of reinforced concrete material relative to other materials.The reason being that concrete materials are readily available and lower in cost than alternative materials (Hoover et al., 2016). The material of construction should be resistant or slow to corrosion by hydrogen sulphide gas and other possible corrosive contents, therefore concrete tanks should be regularly inspected to prevent leaks of raw sewage that cause soil contamination and pollution by pathogens (EPA, 2017). Contamination of groundwater by failing OWTS may increase concentration of pathogens that may impact on humans (Gunady et al., 2015)

The size of the tank is technically determined by the number of occupants in the house. For large systems with number of bedrooms more than six or systems other than residential, the tank is to be sized using the following formulae:

$V \text{ (litres)} = 0.75 * Q \text{ (litres)} + 5100;$

Where: V is minimum liquid capacity;

Q is estimated sewage flow per day.

Thus, the volume of septic tank is dependent on the size and type of building to which it will be connected (Health and Social Services, 2017).

A typical septic tank system may include the following:

- sanitary plumbing fixtures;
- a septic tank;
- a pumping sump; and

- a soakaway.

The operations of a septic tank system requires that household wastes flow to the septic tank using gravity where initial treatment takes place. Then, aerobic bacteria partly breaks down the sewage within the tank. Heavier solid matter settles at the bottom and forms sludge, whilst light matter floats to the surface and forms scum. Thus, three distinct zones exist within a septic tank, namely: - sludge, clear zone and scum (Moving.com, 2018).

The effective settling of solids is directly dependent upon the detention time within the tank. Minimum detention time should be at least 24 hours to ensure 60 to 70 percent of the suspended solids are removed and *Biochemical Oxygen Demand* (BOD) is reduced by 30 percent. Therefore, the septic tank should be of sufficient capacity to provide for a 24 hour retention of the daily inflow into the tank.

The design criteria for a septic tank suitable for a typical residential household are:

- minimum daily inflow or hydraulic load of 150 litres per person per day,
- minimum detention of the daily inflow for 24 hours,
- sludge/scum accumulation rate of 80 litres per person per year,
- daily inflow based on not less than six persons,
- disludging frequency of atleast once in three years , or more often where high solid loads are experienced.

Excessive build up of sludge and scum reduces the capacity of the clear zone, resulting in discharge of untreated sewer to the subsurface. Properly constructed or installed septic tanks and absorption field coupled with proper care and maintenance can mitigate groundwater contamination and provide many years of service (EPA, 2017).

2.6 Use and maintenance of septic systems

Observing proper maintenance procedures and regular pumping are important in avoiding septic tank system failures that may lead to groundwater contamination. Failure to pump out a septic tank when required may result in sludge or scum being carried over to the disposal field, resulting in clogging of the soil and complete failure of the system (Health and Social Services, 2017). The septic system requires regular maintenance, failure to maintain the septic tanks by pumping out the sludge at the recommended rate of once every 3 years and disposing it in a proper manner is also a challenge for some users especially where there is an overwhelming demand for this service (Connecticut Department of Public Health, 2018). Septic tanks effluent discharged into soil carries various constituents that may reach and degrade groundwater. Some may be natural chemicals like chlorides, nitrates, phosphates oil fractions, fuel oil, pesticides, chlorinated hydrocarbons, turpentine etc. Some common reasons for failures of on-site sanitation include: insufficient plot area for ground infiltration of waste, ground infiltration failure due to soil percolation rate, surface water pollution and groundwater pollution (USEPA, 2017).

A well maintained septic tank and drain field can last for many years. Maintenance practices that are important are as follows: Minimizing the load or volume of water entering the septic tank, regular inspection of atleast once in a year, pumping out the septic tank regularly, ensuring that the site drainage is adequate and properly landscaped. Septic tanks should be pumped out every three to five years. Maintenance should be done by professionals familiar with proper procedures and having adequate equipment for pumping waste. (Wickell, 2018).

The purpose of the drain field or soakaway is to receive partially treated sewage from the outlet of the septic tank for underground infiltration through soil which purifies this liquid by decomposing organic matter. Further, the waste water is also discharged by vaporization and evapo-transpiration (Mechtensimer, 2017).

The area around the soil absorption system should never be used as a traffic area for vehicles and pedesstrians to avoid compacting the soil. When the soil around the drain field is compacted, failure can occur as waste water would fail to percolate through the ground. (Health and Social Services, 2017).

Sewage system designs are based on site soil characteristics to protect groundwater contamination, hence protect residents from exposure to water-borne diseases. The size, design and cost of installing a sewage treatment system vary depending on depth to bedrock, slope, soil texture and permeability (Licking County Health Department, 2015) .

2.7 Septic tank performance requirements

Septic tank Performance requirements are set by limiting the risks they pose to groundwater resources. The specific parameters which get affected by septic tank effluents are physical, chemical, and biological properties of groundwater (Leslie, 2015). As the septic tank system is used, there is build up of sludge at the bottom of the tank. Therefore, the volume of the tank reduces leading to less retention time of waste in the tank. This ultimately leads to untreated waste being offloaded to the drain field, hence contaminating groundwater (US EPA, 2015). The other problem associated with septic systems is having many septic systems in a given area which will overload the soil's natural purification systems and allow large amounts of wastewater to contaminate the aquifer (Banda, 2013).

2.8 Location and construction of boreholes

Location of boreholes by any standard is supposed to be as far as possible from any potential source of contamination such as septic tank systems (Fulazzaky, 2014). However, due to limitations of space, a minimum distance has been set between a borehole and a septic tank. Accoording to UNHCR (2006), the minimum distance between a borehole and septic tank is 30 metres (UNHCR, 2006).

In order to correctly locate the borehole, there are a number of factors which must be considered to mitigate cotamination of groundwater.These factors include surface drainage, groundwater flow and use of technological equipment for proper location (Kanyerere et al., 2012).

Construction of boreholes involves sealing off the upper surface of the bedrock with casings and ensuring that the surface is properly grouted in order to minimise the risk of run-off water from entering the borehole (Makela, 2012).

2.9 The effects of urbanization on groundwater quality

According to the results of the 2010 population census, Zambia's population is concentrated in Lusaka and the copperbelt cities of Ndola and Kitwe, making rural areas under populated. In these Cities more than 60 percent of the population live in unplanned settlements where infrastructure services are either missing, inadequate or in poor condition (World Bank, 2015).

Furthermore, development of the urban infrastructure such as water and sewerage systems have been overlooked. This has led to a total disregard for social, aesthetic and environmental long-term impacts on the areas (Ibid). This has resulted in high population densities, overcrowded housing, unsanitary conditions, and diminishing open spaces which makes it difficult for the LAs to provide the required sanitation facilities. LAs also lack adequate capacity to implement and manage urban development (UN/DESA, 2013).

2.10 Borehole design configurations

A borehole is a narrow shaft drilled in the ground, usually vertically. It is constructed for a purpose of groundwater abstraction for either domestic or other uses. Boreholes are an effective way of tapping into the water bearing aquifer below the ground and pumping water to the surface. A borehole has to be properly designed, professionally constructed and carefully drilled. The principle water bearing strata is termed as aquifer. An aquifer is defined as a geologic formation from which water in usable quantities can be obtained. There are three classification systems for types of wells; the following are the classification of wells.

a) Method of construction, that is, dug or drilled,
b) Purpose of use – water supply well, test well, observation well, monitoring well, special purpose well, injection well, or disposal well;
c) Formation in which the well is completed – consolidated (bedrock), or unconsolidated (alluvial/poorly unconsolidated) well (Defo et al., 2016).

This dissertation only focuses on the drilled wells for purposes of water supply as a case for Meanwood-Kwamwena, Lusaka.

2.11 Groundwater

Groundwater is the water reserve found underground in the cracks and spaces and moves slowly through geologic formations of soil, sand and rocks and aquifers beneath the land surface. It is found below the water table in soils and geological formations that are fully saturated; the pore spaces within the rock or soil matrix are filled or saturated with water. Groundwater occurrence is widespread in many environments and a very important supply for many purposes including domestic, agricultural and industrial use (Vaughn, 2015). It is estimated that 60 percent drinking water in Lusaka is abstracted from groundwater while 40 percent comes from Kafue River, 45 km south of Lusaka city. Currently, LWSC pumps 125,000 to 140,000 m^3/day from the local groundwater systems (ADB, 2015a).

2.11.1 Groundwater contamination

Groundwater can be contaminated through natural occurrences or anthropogenic (man-made) activities. Naturally-occurring contaminants typically come from dissolving rocks, soil, and decaying plant material. Man-made contaminants include Fertilizers, pesticides, leaking storage tanks, human waste from leaking septic tanks and waste water systems. Agricultural and industrial activities are sources of groundwater contamination. (California Water Board, 2012).

Groundwater is a resource that is available and is reliable even during prolonged dry seasons because of the large storage and is cheaper to develop. If unpolluted, it requires little or no treatment and it can be tapped where it is needed. As a result, groundwater is important for human water supply in urban and rural areas in developed and developing nations alike. Thus, groundwater is key in water supply in the selected areas of Lusaka (WHO, 2014).

However, in certain regions, research findings show that groundwater has been contaminated and that it contains contaminants that are dangerous to human health. In its natural state, the constituents of groundwater depends on the composition of the soil which has organic matter (humic substances) and minerals such as Ferrous ion (Fe2+), Manganous ion (Mn2+), Ammonium Cation (NH4+), Hydro sulfuric acid (H_2S), Bicarbonate ion (HCO3-), Silicon dioxide (SiO_2) and Fluoride ion (F-). The composition of groundwater is affected by human polluting activities such as agriculture, industrial and domestic activities (Ibid).

Groundwater quality is expected to further deteriorate over the next decade and this will augment threats to human health, environment and sustainable development (UNESCO, 2018). Also, it is known that groundwater is a resource that sustains life to people, animals and plants. The rate at which the world's groundwater is diminishing compared to that of natural recharge of the aquifer required to support ecosystems, has not yet been fully determined (ibid).

The supply of sanitation facilities and water in Zambia is characterized by limited access both in rural areas and urban settlement areas (Mumma et al., 2011). The utilities that are mandated to supply water, do so with their own limitations resulting in inhabitants looking for alternative water sources (ADB, 2015a).

The pollution of groundwater resources is often a consequence of inadequate planning for land use, resulting in the practices of high risk activities in places where they have a negative impact on groundwater resources. A holistic approach is therefore required in the management and protection of groundwater resources. Increasingly, methods that protect groundwater resources are being incorporated into land-use planning, or at least considered in the approval of new developments. The development and acceptance of Environmental Impact Assessment legislation has brought the impact of developments on groundwater resources to the attention of many decision makers. Without an elaborate sewerage system in rapid growing population, human health will always be at risk due to likelihood of a disease outbreak occurring (Rashid et al., 2017). Due to over reliance on groundwater by residents of parts of Lusaka, precaution must be taken since sewer water and groundwater might come into contact with each other and expose residents to various health hazards (World Bank, 2015).

2.11.2 Mechanism of Groundwater Contamination

Point sources of pollution are described as those that are readily identifiable and typically discharge water through systems of pipes, but non-point sources originate from a wider area (Mali et al., 2015). Septic tank systems are a non-point source. Comparison with streams or rivers, the flow of groundwater is very slow and has very little turbulence or mixing. As a result, when a contaminant enters into the groundwater, it is not disturbed. It forms a flux of high concentration of the contaminant within the fluid (a plume) that flows along the same path as the groundwater. Among the factors that determine the size, form, and rate of movement of the contaminant plume are the amount and type of contaminant and the speed of groundwater movement (Ibid).

The contaminant plume as shown in Figure 2.1 is often found down-gradient from a point source of pollution, not easily noticed and can stay in the water even for years until the water is abstracted from the borehole. Size and speed of plume depends on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding water. Groundwater and contaminants can move rapidly through fractures in rocks. Also, groundwater can become contaminated from natural sources or numerous types of human activities: residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality. Furthermore, the size of a community that produces unacceptable groundwater pollution is determined by many factors which are:

- The number and size of infiltration systems,
- The depth to the water table,
- Soil and rock conditions within and above the aquifer,

The aquifer depth and groundwater flow rate and direction (Datta et al., 2016). If the Septic Tank-Soil Absorption System (ST-SAS) in developed settlements are not located properly, poorly built or unmaintained, they can allow contamination of groundwater by synthetic detergents, anions, cations, bacteria and viruses. In isolation, an individual ST-SAS has got no impact as far as contamination to groundwater is concerned (Mbugua, 2016). When considered collectively, the number of such systems and their wide spread use in every area that does not have a public sewage treatment system makes them serious contamination sources (US EPA, 2015).

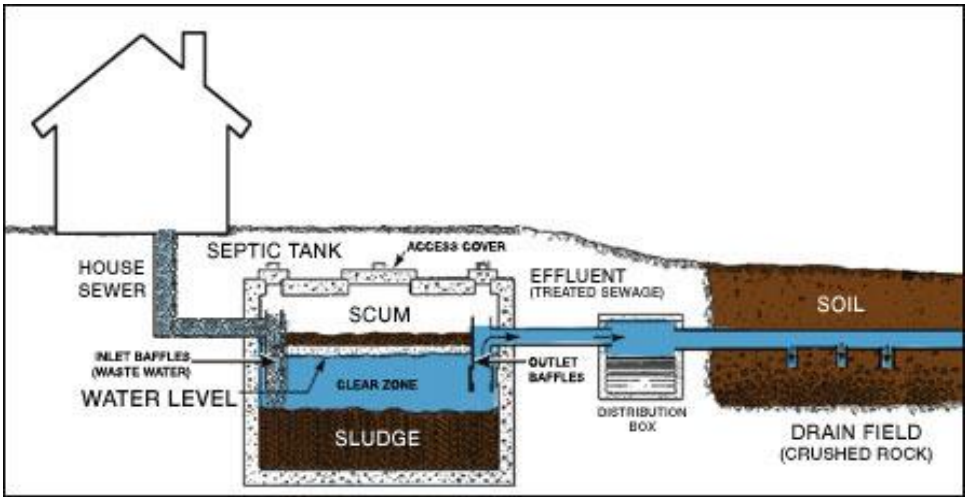

Figure 2.1: Septic system showing mechanism of groundwater contamination by a septic plume below the soak pit (**Source:** University of Maryland, 2015).

Virtually all onsite sanitation systems will pollute surrounding soil. This pollution takes two forms: bacterial and chemical. Bacterial pollution is a direct health hazard and is usually quickly rendered harmless by natural processes. Chemical pollution is predominantly nitrogenous and can increase the level of nitrates in the water. Also, chemical pollution is more problematic than bacterial pollution because it is long lasting and more difficult to remove (EPA, 2012).

2.11.3 Groundwater contamination from ST - SAS

Pollution from a single ST-SAS is expected to be unlikely when located at more than fifteen metres. A more significant consideration is the cumulative pollution produced by a large number of septic systems in a confined area. Shallow groundwater abstracted within the area will almost certainly be contaminated by bacteria and chemicals. Deep groundwater and abstraction points downstream of the area may be contaminated by chemicals. Nitrates dissolve in groundwater without degradation and that is why it is usually found as a contaminant due to ST-SAS (Leslie, 2015).

For many years now researchers have identified some indicators to assess impacts of septic tanks on the quality of groundwater. For instance, the concentration of nitrates in community water supply wells was associated with the concentration of septic tanks in the area, geological features and type of land use (Banda, 2013).

Indicators of contamination from septic-tank systems also include household-cleaning products, chemicals in personal-care products, pharmaceutical compounds, and pesticides.

Microbiological and chemical pollution indicators have seasonal variations whereby, in another study, analysis from the wet season found double the count of fecal coliforms and higher concentrations of nitrate and phosphate than samples from the dry season (Lim et al., 2017).

The point at which the pollution becomes unacceptable will normally be when the concentration of chemical indicators such as nitrates exceeds WHO recommendation of 50 mg/l (WHO, 2014). Contamination in groundwater happens in places where there are many ST-SAS producing a large quantity of organic contaminants within a confined area. The issue of unwanted pollution due to unsanitary septic systems is made more serious when the residents in the same area depend on the boreholes as the only source of water for drinking. Other likely inorganic contaminant substances from septic tanks include phosphates, nitrogen compounds, chlorides, and metal ions. Ammonium (NH4+), from the ST-SAS infiltrates the soil whereby nitrogen is oxidized to nitrite (NO^{2-}), then further oxidized to nitrate (NO^{3-}) by obligate autotrophic micro-organisms. Nitrate has the highest mobility in saturated and unsaturated soil conditions, travelling with little transformation in water over long distances if the right conditions are present. However, NO^{3-} can be immobilized when taken up by plants within the immediate area (Lim et al., 2017).

Water becomes polluted once its funtions and qualities in its natural state are not standard. Pollution of natural water sources is mainly from domestic and industrial waste being discharged into the aquifer. Water for domestic use, including drinking, should be within specific ranges of physical, chemical and biological parameters (Kochary et al., 2017).

The same parameters have been reserched on and adopted as a reference to ensure that the water is suitable and safe for drinking. Any deviations of parameters from the listed range of minimum and maximum contaminant levels will imply that water is of poor quality that is unsafe for drinking (Mbugua, 2016).

Water pollutants may be broadly classified as: organic, inorganic, sediments, radioactive material and thermal pollutants. Substances that contaminate water and result in pollution that is of an organic nature are; oxygen demanding wastes, disease causing agents, plants nutrients, sewage, synthetic organic compounds and oil (Kochary et al., 2017).

Anthropogenic activities that have been going on for a long time have contaminated groundwater which eventually has resulted into the deterioration of physico-chemical and biological properties. Disposal of grey matter is also another neglected challenge facing rapidly growing human population over the world (Alexander, 2015).

OWTS are the main sources of wastewater to the ground and are the most frequently reported causes of groundwater contamination (Leslie, 2015). The absence of piped water from utility companies has necessitated a need for other reliable and sustainable source of water. Groundwater has been a ready source. Therefore, the sub-surface environment within which groundwater is reserved could be exposed to contamination by disposal of waste in the soils. Most soils can filter solids including pollution solids. However, this ability varies with different sizes, shapes and arrangement of particles. Clays and other selected minerals capture and exchange some elements and compounds when they are in solution. Such exchanges are important in the capture of pollutants such as heavy metals. Due to wide spread concerns about the impacts of OWTS on groundwater, a wide range of technologies have been developed by scientists to address removal of pathogens and nutrients from on-site waste water (Chang, 2014).

Groundwater reserves are maintained by a hydrostatic balance within the soil pores, below the water table which is naturally recharged by rain water, streams or rivers. The same groundwater also discharges from streams or from drilled wells e.g. boreholes. Over-pumping or over abstraction of groundwater from boreholes (where there is a declining groundwater level) may lead to infiltration of septic tank effluents (McKibbin, 2015).

2.12 Total, faecal and E. coli bacteria in groundwater

Total coliforms and Feacal coliforms are main indicators that the groundwater is contaminated. Coliform bacteria are described and grouped, based on their common characteristics, as either Total or Feacal Coliform. The Total group includes Fecal Coliform bacteria such as Escherichia coli (E .coli), as well as other types of Coliform bacteria that are naturally found in the soil. Fecal Coliform bacteria exist in the intestines of warm blooded animals and humans, and are found in bodily waste, animal droppings, and naturally in soil. (The British Columbia Groundwater Association, 2007).

2.13 Septic Tank Treatment System

A septic tank is a waste water treatment system which uses a tank as a primary holding device. It is a water tight container that collects and provides treatment of waste water by holding raw domestic effluent from the households so that the denser solids are sedimented as sludge and settle at the bottom of the tank and floatable solids rise to the top to form scum. They are designed to provide basic treatment which partially destroys pathogens that are found in the human waste (Tilley et al., 2012). The main pollutants from septic tanks are parasites and viruses that cause illnesses such as gastroenteritis and shigellosis. These are synonymous to feacal wastes (Mbugua, 2016).

2.14 Septic Tank Configuration

The Septic tank configuration includes the septic tank, the effluent treatment component and all piping in between. Drainfields also known as leachfields or absorption fields and soakaways are commonly used for effluent treatment where soil has a suitable percolation rate (Hygnstrom et al., 2008)

The important factor in the septic tank design is the relationship between the liquid surface area, the quantity of sewage it can store and the rate of waste water discharged. Each of these factors will impact the tank efficiency and the amount of sludge it retains (EPA, 2017). The tanks have different shapes and capacity, typically as shown in Figure 2.2.

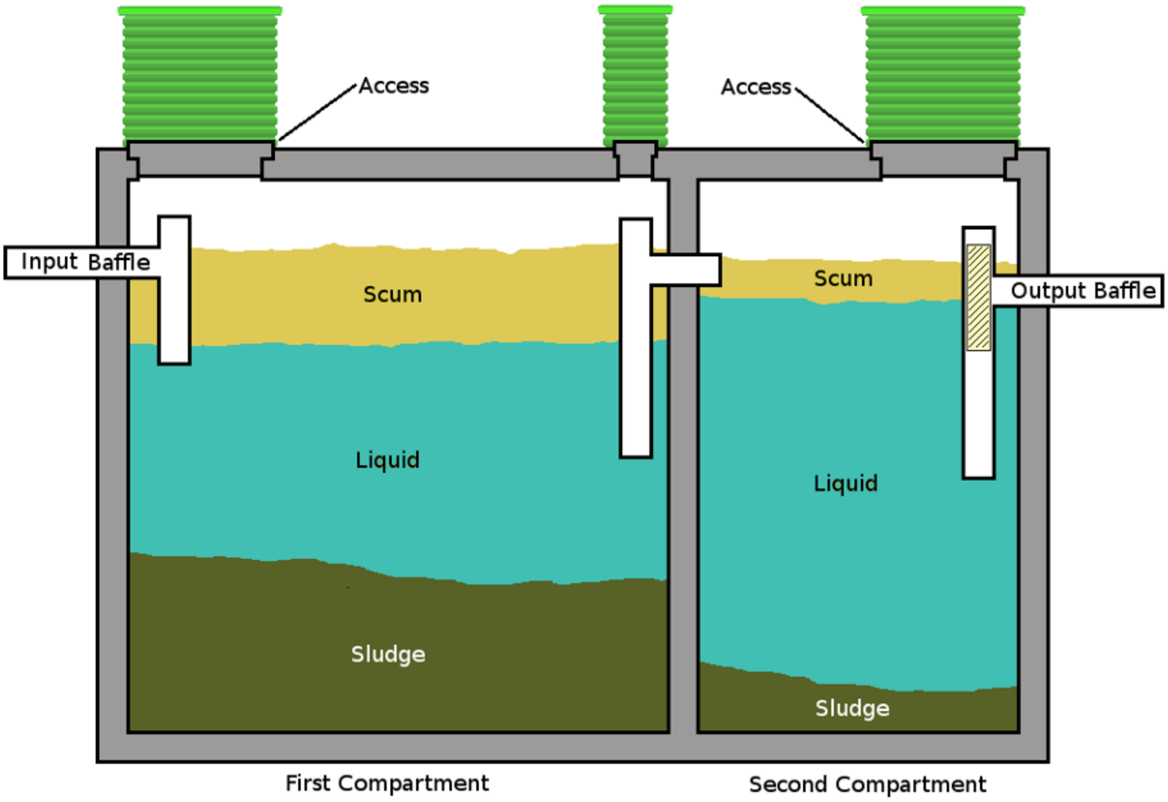

Figure 2.2: Schematic diagram of a septic tank, showing the three layers of a Septic Tank **(Source:** University of Maryland, 2015).

In addition, the dimensions of standard soakaway ranges from about 1.22m to 1.83m in diameter, and 1.22m to 3.05m in depth (Mechtensimer, 2017).

2.15 Effects of Soil Permeability On Efficiency of the Septic Tank

Septic tank failure occurs in compacted soil with low permeability, high water table, areas with clay, and impermeable rock near surface. The soil structure has a big role to play in determining soils permeability. Permeability is an important factor to consider for septic system sites. In some areas which have shallow soils, at most 3.05m, over impermeable bedrock, the sewage can discharge through leach lines located at higher elevations and could raise the groundwater level and flood leach fields at lower elevations (Waller, 2016). Soil acts as a sieve for these microbial pathogens, however as their sizes get smaller, the trapping is less efficient. The efficiency of the soil to purify this is also affected by other factors including soil pH. In this regard it is concluded that microorganisms travel further and more efficiently in saturated soils than in unsaturated soils. Bacterial retention is higher in fine textured soils which is a major limitation to movement through soil (Mbugua, 2016). Also, saturated soil facilitates movement of pathogens and chemicals to the groundwater table. Mounds may form over two kinds of barriers. One kind is clay or other low permeability stratum; the other is groundwater table surface. Mounding may be more of a problem in septic systems installed in some stratified soils with low permeability and especially if they are concentrated within a small area (Department of Environment Labour & Justice, 2013).

Coarse textured soils absorb much rainfall which creates a layer of saturated soils. While raining, bacteria and viruses may be washed down. Mounding on effluent can raise the level of groundwater and increase the danger of contamination by septic tank effluent. Movement of typhoid causing bacteria, through at least 0.92m to 1.22m of sand and 64.05m of saturated soils (distance from bottom of soakaway to groundwater table) has been reported and that, lateral and downward movement of leachate can be up to 30m down, and that rainfall desorbs microbial pathogens including viruses and carry them down in still viable states. It was also concluded that, vertical separation between soakaway and borehole are more important than the horizontal separations between soakaway and borehole (Hoover et.al., 2016).

2.16 Sitting of Septic Tank

The municipality recommends that, septic tank sitting in a construction area should be at a general distance of six metres all around any structure, a dwelling house or a perimeter boundary, which would result into an embankment. If sewage flows downwards through a porous material and is stopped or slowed down by a barrier, it accumulates above the barrier and forms a dome. The hydrostatic pressure builds up and pushes the sewage laterally (Department of Environment Labour & Justice, 2013). When this dome forms below a soakaway or drain field, the separation between the bottom of the soakaway and the groundwater may decrease to less than recommended and it may grow high enough to flood the soakaway.

The national building code, gives the guidelines and regulations on sitting of septic tanks and soakaway, such that they should be impervious to liquid (NBR, 2014). Soil evaluation and soil percolation tests should be considered as factors for sitting the septic system. The site evaluation is the first step towards installing a septic system and involves gathering detailed information about the lot and the surrounding area. This information includes the topography, separation distances, owner's preferences, physical properties of the soil, existing water sources and the depth to any limiting layer. The most important factor in determining whether an onsite system will work on a particular site is the soil properties and the soil's ability to treat and dispose the wastewater (Goulding, 2016).

2.17 The Significance of PH value in Water

The pH (pondus Hydrogenium) is the degree of the basicity or acidity of a water solution or simply as the measure of hydrogen ion [H]+ concentration of a water solution. pH has no unit of measurement, since it is a dimensionless quantity, by virtue of its logarithmic nature. It is a parameter that determines the quality of all waters, which also affects most physical, biological and chemical processes in water supply treatment (Goulding, 2016).

Water in its pure state has a pH of 7 (neutral) and the exact values depend on temperature. For most natural waters, the pH ranges from 6 to 8.5. Values below 7(acidic waters) in waters that are high in organic content and values above 7 (alkaline waters) in eutrophic waters, groundwater brines and salt lakes. However, for clean water, the pH may be due to the types of rocks and vegetation within the watershed (WHO, 2014). Permissible pH value for public water supplies ranges between 6.6 to 8.4. The pH of water is a measure of its acidity/alkalinity, which in turn has an effect on metals and concrete. Low pH can increase corrosion, while too high a value can lead to calcium carbonate deposition and encrustation of pipe networks (IRC, 2002).

Major reasons for variations of pH in water are; industrial and domestic effluent and acid rain from atmospheric depositions. Respiration and photosynthesis of algae in eutrophic waters can also cause fluctuations of pH in water (WHO, 2014).

2.18 Chemical toxicology

The US EPA, under the Safe Drinking Water Act established water regulations in order to bring down levels of over 80 contaminants in groundwater closer to recommendations of Maximum Contaminant Level Goals (MCLGs) previously established by the EPA (UNEP, 2016a). For nitrate, the MCL is 10 mg/L (ppm) as nitrogen. The basis of the action taken by the EPA, setting the MCL at 10 mg/L, was the occurrence of methemoglobinemia in infants under six months. The MCL reflects the levels at which this condition may occur, mitigation measures must be implemented so that the child should not suffer from methemoglobinemia. People, who depend on groundwater would be safer from this disease if their boreholes are routinely tested (UNEP, 2016b).

2.19 Physical, chemical and biological characteristics of Water

Water has three characteristics, i.e. physical, chemical and biological characteristics. Physical characteristics of water are temperature, colour, turbidity, odor, taste and solid content. Taste and odor water can dissolve many substances giving it varying tastes and odors. However, pure water is tasteless and odorless (EPA, 2011).

Chemical Characteristics of Water are Total Solids and Suspended Solids, pH value of Water, Hardness of Water, Chloride Content, Nitrogen Content, Metal and other chemical substances in water and Dissolved gases (Ibid)

In Physico-chemical analysis, substances that make water unfit for drinking at concentrations higher than the existing standards for proper health are investigated. These investigations help to establish quality on groundwater (WHO, 2014).

The most important biological organisms in water are pathogens as they transmit diseases Examples of biological organisms include species of bacteria, viruses, protozoa and helminthes (EPA, 2011).

Bacteriological analysis investigates both quantitative and qualitative microbial contaminants in the water. The importance of bacteriological analysis of drinking water helps to determine the presence of potential water-borne pathogens. Therefore, bacteriological analysis of water provides the most sensitive quality parameter (WHO, 2014). Table 2.1 shows the Scale of measure of bacteriological water quality.

Table 2.1: Scale of measure of bacteriological water quality

Parameter	Indicator	Scale of measure	
Bacterialogical water quality	No. of feacal coliforms (E. coli) in 100ml of water	Nil Any presence	Satisfacory Unsatisfactory
	Total coliforms in 100ml of water	0 to 10 cells More than 10 cells	Satisfacory Unsatisfactory

Source: UNHCR (2006)

2.20 Physical features of the City of Lusaka

Lusaka is the largest and Capital city of Zambia. It is at 15°25'S, 28°27'E, and at an altitude of 1,280 m. Lusaka has a humid subtropical hot summer climate that is mild with dry winters and hot humid summers (ADB, 2015a). The city's climatic conditions is divided into two distinct season i.e. rainy season and dry season, and this influences the hydro-geological features of the city (FAO, 2016)

The city has ten (10) major land uses which include residential, commercial, industrial, agricultural, institutional, parks and recreation, cemetery, open spaces, administration, roads and utilities with residential being the largest land use, which puts pressure on groundwater utilization and also the aspect of groundwater contamination (Ibid).

The principal legislation that guides land use planning in Zambia is the urban and regional planning act no. 3 of 2015. This act provides for the establishment of a planning framework for administering and managing urban and regional planning in Zambia. Under this act, the responsibilities of the MLG are to:

i. Appoint planning authorities and delegate functions to them,
ii. Order the preparation of regional structure and local area plans and to approve, revoke or modify such plans,
iii. Approve or reject applications for subdivision, development of land or change in use,
iv. Consider appeals against rejection of applications by planning authorities for development,
v. Recommend the acquisition of reserve land for development purposes,
vi. Ensure enforcement of development control (MLGH, 2015a).

Groundwater in Lusaka accounts for almost 61 percent of the total water supply in Zambia (FAO, 2016). The city's underground hydrology is built over a karstic dolomite aquifer comprised of a complex basement overlain by limestone and dolomite. However its porous and soluble characteristics render it susceptible to pollution (Ibid). Also, the water table in Lusaka is generally close to the surface and hence prone to pollution (Ibid).

Increased rate of urbanization and lack of connectivity to water supply system by LWSC has resulted into exploitation of other sources of water supply to households, which involve construction of private boreholes thereby exerting enormous pressure on the Lusaka aquifer (ADB, 2015a).

Geology: The Lusaka dolomite is the most dominant and important aquifer in Lusaka and surrounding areas. The Lusaka dolomite belongs to the category Karst aquifer. The formation consists of dolomitic marbles, a type of metamorphosed dolomitic limestone. The dolomite contains a system of interconnected caverns and channels of various sizes (BGR, 2012). Meanwood-kwamwena which is within the catchment of Lusaka City and Chongwe District is built on the same aquifer. The Lusaka aquifer is high yielding and has a large storage capacity of groundwater (Ibid).

The Lusaka dolomite comprises a wide range of different rocks according to changing contents of magnesium (Mg), calcium (Ca), iron (Fe), clay minerals and organic matter. It also constitutes other subordinate aquifers within marbles that are of cheta formation located to the south and north of the main aquifer. Some minor aquifers have also developed in schist's and quartzites of cheta and chunga formation and within alluvial deposits (ADB, 2015a). Table 2.2 shows the Lusaka rock formation.

Table 2.2: Lusaka rock formation

Formation	Sub-formation	Type of rock	Age	Remark
Alluvium	Loose or semi-consolidated sediments	Quaternary to Recent	Alluvium	
Katanga	Lusaka Dolomite	Crystalline dolomite (dolomitic marble), dolomitic limestone and limestone	Neo-Proterozoic (Pre-Cambrian)	Main aquifer in Lusaka; type Karst Aquifer (Lusaka Karst Aquifer)
	Cheta Formation	A sequence of different types of schist which are intercalated by crystalline dolomite (dolomitic marble), dolomitic limestone and limestone; the formation contains as well some quartzite.		Cheta Formation
	Chunga Formation	Mainly schist; minor carbonate rocks and quartzite intercalated		Chunga Formation

Table 2.2 continued

Formation	Sub-formation	Type of rock	Age	Remark
Basement		Mainly gneisses; some dolomites and quartzite are intercalated.	Proterozoic (Pre-Cambrian)	
Igneous rock		Basalt	Cretaceous	More or less impermeable for groundwater
		Lusaka granite		

Source: ADB, 2015a

Topography: Lusaka stands at 1,280m above sea level and is overlain by flat topped hills marking prominent quartzite horizons. Dolomite and limestone form flat lying area, where as schist and quartzites underlie more broken, hilly country and the order quartzites in particular form extensive ridges several metres high. Schist-dolomite boundaries are usually indicated by steep downward slopes from schist to dolomite. The general topography is important especially in the mitigation of groundwater contamination involving septic tank systems. Flat terrains make it difficult to drain and the area becomes vulnerable to flooding (Ibid). Figure 2.3 shows the Topographic map of Meanwood Kwamwena and surrounding areas.

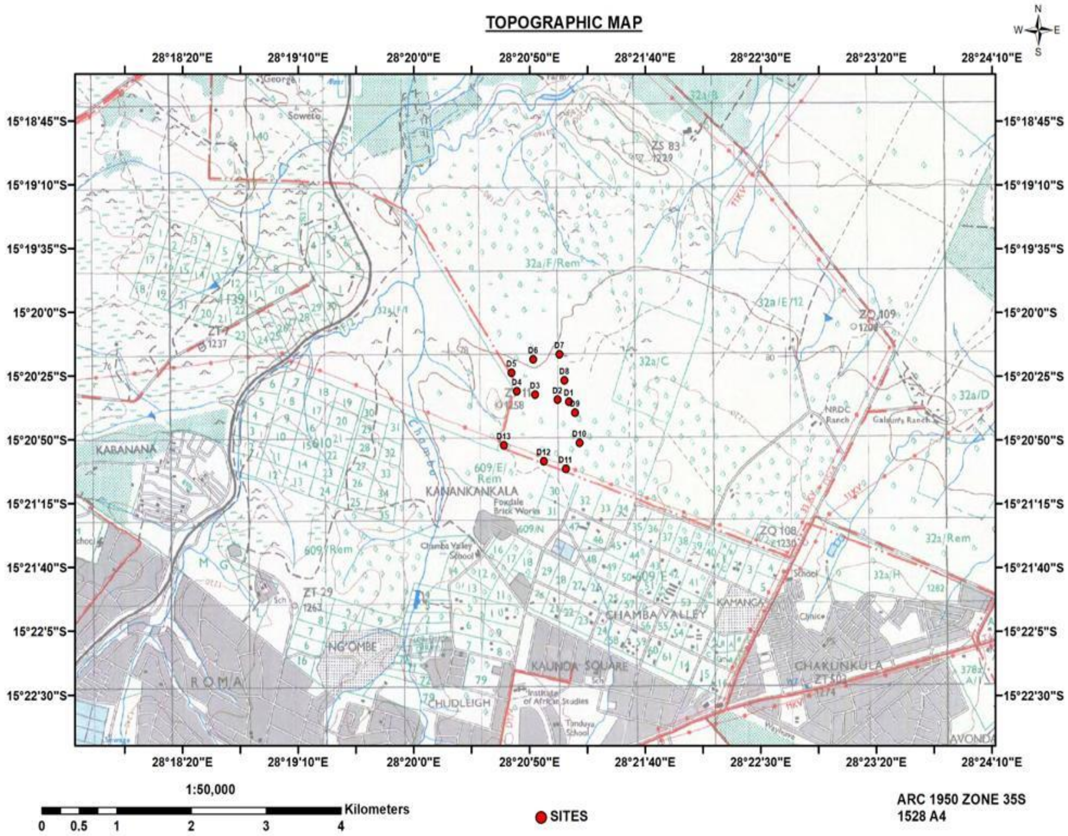

Figure 2.3: Topographic map of Meanwood Kwamwena and surrounding areas.

Soils: There are four distinct soil types in Lusaka and they correspond to geological formation. The specialized plateau soils found on the Lusaka Dolomite are; Plateau soils found immediately north of Lusaka dolomite outcrop and in the north east are; upper valley soils (Ibid).

Four distinct soil groups are recognized as follows:

1) **Specialised plateau soils**. In the south and west of Lusaka dolomite outcrops and parts of the calcareous horizons of the Cheta formation are overlain with thin clay, or fine sandy soils, often containing large numbers of laterite pisoliths., where laterite reaches the surface and forms hard undulated pavements with little soil cover (Ibid);
2) **Plateau soils**. North of the Lusaka Dolomite outcrop are the fine sandy soils typical of the plateau are products of prolonged weathering of dominantly acenaceous rocks on an eroded landscape (Ibid);
3) **Upper valley soils:- type i**. South of the laterite soil zones, are rich red-brown and dark brown loams of mixed colluvial origin (Ibid); and
4) **Upper valley soils: - type ii**. South-east of a line through Ngwerere and Chikumbi sidings, are sandy loams. The soils are thick and mixed colluvial and alluvial origin. (Ibid). Figure 2.4 shows the geology of Lusaka.

Figure 2.4: Geology of Lusaka **(Source:** MCC, 2013)

2.21 Study site

Meanwood-Kwamwena is relatively a newly developed area on the northern part of Lusaka. It is a medium cost housing area and about 15 km from the Lusaka Central Business District. Kwamwena Valley is located 4 kilometers off the Great East Road -Munali round-about.The area is predominantly medium cost residential and is well planned. It covers about 600 ha of land. The area has about 7,100 plots most of which have had the buildings completed (Meanwood Property Development Corporation Limited, 2017). Figure 2.5 shows the Meanwood-kwamwena spacial map.

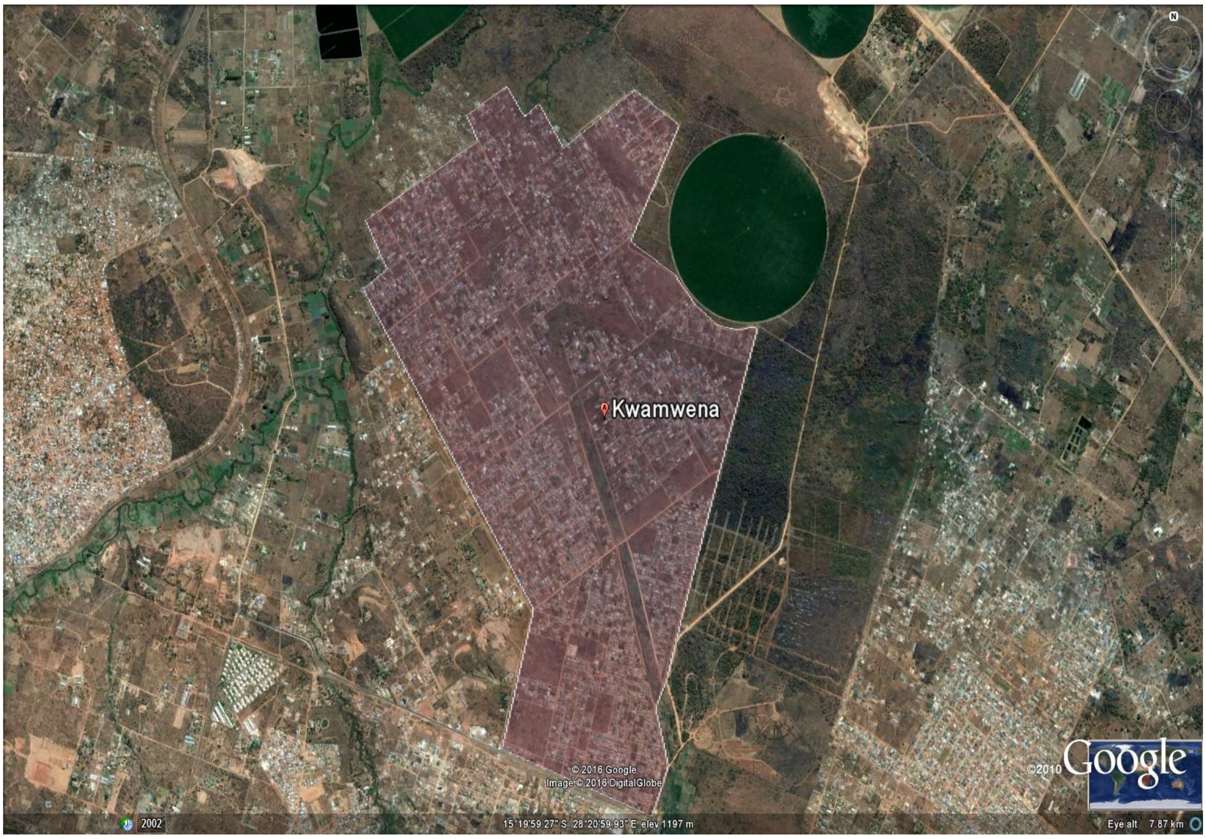

Figure 2.5: Meanwood-Kwamwena spatial map (**Source:** ADB, 2015a)

It is a medium-income population and there is no existing piped water supply system and sewerage network in the area and the residents depend on a number of water sources which include:

i. Boreholes, which are owned by individuals and are between 50m to 100m deep,
ii. Roof catchment: Some residents harvest water from the roofs during the rainy season (MCC, 2013).

At present, residents rely on onsite sanitation solutions. The area is also prone to flooding making construction of onsite sanitation facilities a challenge. Hence, the need for mitigating measures on septic tank effluents on groundwater quality which in turn, would alleviate the major challenges experienced (Ibid).

The area is also a valley which is in this case a natural recharge area, yet this is likely to be disturbed as it has become a settlement site. As a settlement site, the likelihood of drainage systems is eminent which would ultimately impact negatively on the aquifer levels as underground water recharging will be affected (Ibid).

The area is also significant in the aspect of its proximity to the airport. This could likely bring with it a tangible source of income by way of Lodges and other facilities supporting such like activities. However, the Kaunda Square ponds in the proximity of the area pose another challenge. If the ponds are not well maintained, sewage is likely to seep through the water aquifer and pollute underground water in the long run – to the detriment of resident's health on the basis of water borne diseases due to faecal matter contamination. As a matter of fact, residents currently depend on on-site sanitation facilities, including water abstracted from borehole and pumped into overhead tanks as shown in Figure 2.6 (Ibid).

Figure 2.6: Typical private domestic water tank supplied from a borehole in Meanwood-Kwamwena

2.22 Aquifer, Drainage Pattern and Water Table of Lusaka

2.22.1 The Lusaka karst aquifer

Of special interest with respect to groundwater are the Lusaka Karst aquifer (LSKA) and the carbonate rocks of the Cheta Formation. The formations are shown in Figure 2.3. Other rocks underlying Lusaka area, which are mainly of schist of the Cheta and Chunga formation, and are impermeable to groundwater. Only in case of intercalated quartzite and carbonate rocks or through the presence of joints and faults, open spaces exist and enable groundwater to be connected to that of a different carbonate unit. Principally the same applies to igneous rocks i.e. basalt and granite, and the gneisses of the basement which also form a geological part around Lusaka (ADB, 2015a).

The tectonic structure of Lusaka area is characterized by a set of northwest to southeast trending synclines and anticlines which are related to each other through a complicated set of faults, major disturbances and over-thrusts. Figure 2.6 indicates that the LSKA constitutes the core of a syncline. Through the tectonic arrangement, the different aquifers i.e. karst aquifers and joint aquifers are hydraulically connected. The groundwater flows through a system of fault lines, joints and other lineaments (Ibid).

The area is severely folded. The axes of the synclines and anticlines trend in northwest and southeast directions. A set of joints can be found which are comparatively perpendicular to the main axes. These joints are partly open and play an important role in the flow of groundwater. Fresh and undisturbed marbles and crystalline dolomites are compact and impermeable to groundwater. Through tectonic results and reduced gravity pressure near the surface, these carbonate rocks may develop fissures and cracks. Groundwater starts to circulate and to dissolve marbles along those features. As a result, a system of caverns, tunnels, and cavities is generated near the surface. Also, Groundwater potential in such formations is enormous and the LSKA belongs to this category (Ibid). The size and shape of the LSKA is illustrated by Figure 2.7.

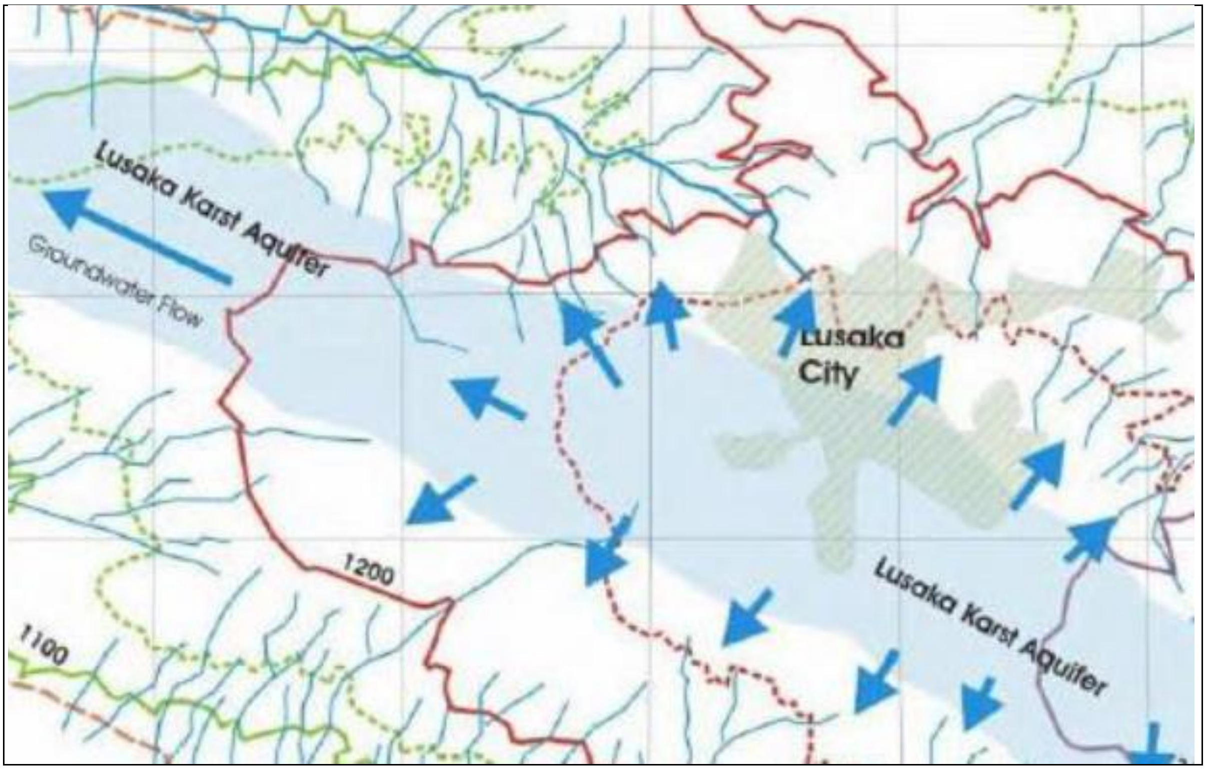

Figure 2.7: Lusaka Karst Aquifer (**Source:** MCC, 2013)

The LSKA forms a slightly elevated flat area with the maximum elevation around 1,300m and minimum elevation about 1,200m above sea level. The elevation contour lines shape the LSKA as a northwest to southeast trending morphological feature dipping gently to the northwest (MCC, 2013).

2.22.2 Drainage pattern in Lusaka

The drainage pattern of the LSKA shows the surface of the karst area almost without any surface runoff. This is in contrast to the schist bordering the LSKA. There, the drainage developed a dendrites surface pattern. This setup suggests that: a) the LSKA dewaters essentially along the border karst aquifer/schist, on this border numerous springs i.e. overflow springs can be found; b) the LSKA absorbs large quantities of rain water; and c) there is no or little water seeping into the underground within the areas of the outcropping schist (Ibid).

2.22.3 Water table characteristics of Lusaka

The general trend reflects that the water table decreases during the dry season with a complete recovery during the rainy season. The fluctuation of the water table, though at different levels, remains moderate, rarely exceeding 5m. Seemingly, the fluctuations reflect the general behaviour of the groundwater during times of recharge and discharge. It can be observed that the water table of many boreholes reaches the ground surface during the rainy season. Based upon the area of the LSKA and the average borehole depth, the volume of the productive aquifer in Lusaka was calculated as 12 km^3 (ADB, 2015a). Recharge data for the Lusaka area ranges from 37 to 775 mm, i.e. from 5 to 95 percent of the annual rainfall. Recharge is also direct through sinkholes. In areas of outcropping karst, virtually all the rainwater seeps into the underground. In other areas hardly any rainwater will infiltrate the aquifer because of the thickness of the covering soil and high evapo-transpiration (Ibid).

Although the project area lies on a productive karstic aquifer, it is characterized by shallow water tables ranging from 2m to 25m and lacks protective cover. This makes the area susceptible to pollution from pit latrines and septic tanks. There is urgent need to protect groundwater if the quality of groundwater is to be sustained (Ibid)

2.23 Challenges of sanitation in the city of Lusaka

The growth in population and the migration of people into the city has strained the ability of the LCC and LWSC to provide adequate water and basic sanitation facilities in Lusaka. The peri-urban area is made up of unplanned settlements which are densely populated. Sanitation facilities used in these settlements are pit latrines and septic tank systems. Some families have no latrines and depend on either borrowed or shared latrines, or resort to open defecation. The peri-urban areas are prone to diarrheal diseases linked to poor sanitation (Ibid).

Lusaka is usually affected with annual outbreaks of cholera, typhoid and dysentery and this is due to the poor sanitation problem. Only about 10 to 15 percent of the population in Lusaka is connected to LWSC sewer networks. Then, the remaining population is dependent on pit latrines and septic tanks which are located within the plot boundaries. Major challenges are limited space to be utilized for pit latrines and septic tanks, which leads to an increase in groundwater contamination as there is a corresponding concentration of septic tank systems. (Ibid).

2.24 Legal and Regulatory Framework

Most countries in Sub-Saharan Africa have had some policy frameworks in place to direct the utilization and management of both water and wastewater. Attempts to put in place policies and legislative reforms to resource sector institutions stem from a few years of efforts. Despite initiatives undertaken by these countries so far, gaps still exist with the operationalization of new and existing policies and legal frameworks. Thus, water and sanitation delivery is more affected especially in low-income residential areas (ADB, 2015b).

2.25 National Environmental Laws and Regulations

2.25.1 The Millennium Challenge Act

The Government designates MCA-Z as the accountable entity to implement the Program and to exercise and perform the Government's right and obligation to oversee, manage and implement the Program, including without limitation, managing the implementation of the project and its activities, allocating resources and managing procurements (MCC, 2013). The MCA launched the implementation of the MCC Programme. The MCC programme is as a result of an agreement that was signed by the United States of America acting through the MCC, and the GRZ. The Government tasked The MCA-Z to oversee, manage and implement the MCC program in Zambia. The following are the major aims of the Act: a) to expand access to and improve reliability of water supply, sanitation and drainage services in selected urban and peri-urban areas of Lusaka city in order to reduce the impacts of waterborne and water related diseases; b) to generate time savings for households and businesses and reduce non-revenue water in the water supply network by improving water supply and sanitation and drainage services (Ibid).

2.25.2 The Environmental Management Act 2011

The Environmental Management Act, 2011 is another important Act which provides for the following key responsibilities as shown in Table 2.5:

Table 2.3: Responsibilities of the Zambia Environmental Management Act

integrated environmental management, protection, conservation of the environment, sustainable management and use of natural resources
preparation of the State of the Environment Report, environmental management strategies, other plans for environmental management and sustainable development
the conduct of strategic environmental assessments of proposed policies, plans and programmes that have an impact on environmental management
the prevention and control of pollution and environmental degradation; provides for public participation in environmental decision making and access to environmental information
establishes the Environment Fund;
environmental audit and monitoring;
facilitates the implementation of international environmental agreements and conventions to which Zambia is a signatory;
repeals and replaces the Environmental Protection and Pollution Control Act, 1990

Source: ZEMA, 2011

A person shall not get on any project that could be deemed to have an effect on the environment without the written approval of ZEMA. ZEMA shall not grant an approval in respect of a project if it considers that the implementation of the project would bring about adverse effects on the environment. It also has the powers of arrest and prosecution under the Act. The Act states that a developer shall not implement a project unless the project brief or an EIA has been concluded in accordance with the Act, and ZEMA has issued a decision letter. The Act also provides for undertaking of an environmental audit of the project (ZEMA, 2011).

The Act prohibits any person from polluting the water by discharging effluent or wastewater. It states that no person may discharge poisonous, toxic, obnoxious materials into the aquatic environment in contravention of water pollution control standards established by the Agency. (Ibid).

Indiscriminate disposal of waste is prohibited by the Act. It states that no person shall discharge waste so as to cause pollution in the environment. It further states that no person shall transport waste to any site other than in accordance with a license and to a disposal site established in accordance with a license. It also states that a person shall not operate a waste disposal site without a permit or license. Solid waste generated in the project would be handled and disposed off in accordance with this Act (Ibid).

2.25.3 Water Supply and Sanitation Act

The Water Supply and Sanitation Act consolidates legislative actions under The Water Act, National Water Policy and the Water Pollution Control i.e. Effluent and Waste Water Regulations. The responsible ministry for these environmental policies is the MWDSEP. The purpose of these policies is to provide for ownership, control and use of water. The aim is to promote sustainable water resources development with a view to facilitating an equitable provision of adequate and quality water for all users. Also to ensure security of supply under varying conditions (WSS, 1997). The Act provides for the establishment of the NWASCO which acts as a regulator in the provision of water supply and sanitation services. It mandates NWASCO to regulate the sector in a manner leading to improved delivery, efficiency and sustainability. The Act requires NWASCO to disseminate information to the public on matters relating to water supply and sanitation services (Ibid).

2.25.4 Water Resources Management Act

The Water Resources Management Act establishes the Water Resources Management Authority (WARMA) and defines its functions and powers. The ownership of all water is vested in the President. The use and apportionment of all water shall be made in terms of this Act. Any person may make an application to the Secretary of the Water Resources Management Authority for permission to drill a borehole in the ground for primary, secondary or tertiary use. Additionally, the Water Board may authorize the application on conditions as it may consider it fit (WARMA, 2011).

Whenever LAs wish to appropriate any public water for primary or tertiary purposes necessary to the community under its jurisdiction, such LAs could make application to the Secretary, setting out such particulars of the proposed appropriation as may be required by the Secretary. If the public water applied for is being beneficially used for secondary or tertiary purposes, the use required by the local authority may be authorized by the Water Board (Ibid).

Under this Act, a developer who pollutes public water so as to render it harmful to man, beast, fish or vegetation would be guilty of an offence and liable for punishment. It also empowers the Water Officers to inspect and check if the developers are adhering to the set standards so as to prevent pollution (Ibid).

2.25.5 Public Health Act

The Public Health Act provides for the prevention and suppression of diseases in the general public environment and has provisions for management of sanitation and prevention of pollution of water bodies by local authorities (PHA, 1995).

The LAs of any area are empowered by the Act to provide all the required services for mitigating waterborne diseases. The duties of the LAs include maintenance of cleanliness and prevention of nuisances including those arising from unsuitable dwellings. Some nuisances are foul, overcrowded, waste-pipe, drain, sewer and poorly constructed septic tanks. Other nuisances are water sources and reservoirs whose water is polluted yet it is used for drinking, domestic purposes and preparation of food, and any noxious matter, wastewater, flowing or discharged from any premises into any public street, gutter, drainage channel, or water-course not approved for the reception of such discharge. (MLGH, 2015a).

2.25.6 Local Government Act

The Local Government Act is the enabling legislation governing the establishment, powers and operations of local administration and defines the functions of LAs. The Act provides legal authority for the functions of Councils to be discharged (MLGH, 2015b).

2.25.7 The Town and Country Planning Act

The Town and Country Planning Act provides for: the appointment of planning authorities; the establishment of a Town and Country Planning Tribunal; the preparation, approval and revocation of development plans; the control of development and subdivision of land; the assessment and payment of compensation in respect of planning decisions; the preparation, approval and revocation or modification of regional plans (MLGH, 2015a).

2.26 Policies Under the Water Sector

2.26.1 National Policy on Environment

The National Policy on Environment (NPE) is the key policy that coordinates environmental management concerns in Zambia. NPE is designed to create a comprehensive framework for effective natural resource utilization (e.g. water) and environmental conservation which is responsive to the demands of sustainable development. Some of the main purposes of NPE are to: a). regulate and enforce environmental laws; b). ensure environmental awareness and promotion of environmental accountability, while keeping adverse activities to a minimum. NPE also reinforces the strategy to capacitate MLG, MWDSEP and LAs with adequate resources to rehabilitate and extend sewerage systems and other forms of sanitation (NPE, 2005).

2.26.2 National Water Policy

The National Water Policy is the main policy framework for the water and sanitation sector in Zambia. The Policy seeks to optimally harness water resources for the efficient and sustainable utilization of this natural resource. To achieve the national goal of increasing accessibility to safe water, the policy addresses two main categories of water resources management and development. The key outcomes of the policy are to improve: a) management of water resources; b) institutional coordination and; c) defined roles and responsibilities. The policy promotes the use of water resources in an efficient and equitable manner consistent with social, economic and environmental needs of present and future generations (NWP, 2010).

Furthermore, the GRZ implemented several strategies upon adoption of the National Water Sector Policy as shown in Table 2.4.

Table 2.4: Strategies and Responsibilities for the Water and Sanitation's Sector in Zambia

SN	STRATEGY	RESPONSIBILITY
1	Strategy and Institutional Framework for the Water and Sanitation Sector (1995)	Identifies the framework and arrangements for providing water and sanitation services by local authorities
2	Environmental Sanitation Strategy (1998)	Increases the awareness of sanitation in basic social services and outlines the strategy to provide sanitation services
3	Peri-Urban Water Supply and Sanitation Strategy (2000)	Targets water supply and sanitation services to urban low income communities
4	Community Water Supply and Sanitation Strategy (2000)	Primarily targets rural areas, but also peri-urban areas

Source: MLGH, 2015a

2.26.3 National Health Policy

The National Health Policy outlines a statement by the GRZ to set clear directions for the development of the Health Sector in successive National Development Plans and National Health Strategic Plans. The objective of the NHP is to promote hygiene, general access to safe water, acceptable sanitation and food safety in order to reduce the incidence of environmentally related diseases (GRZ, 2012).

Access to safe water and sanitation: - According to GRZ (2012), the population without access to safe water was 41 percent in 2007 and with regard to safe sanitation; over 12.6 percent had no access to toilet facilities. In addition, 34 percent of households dispose of the garbage by dumping. In 1992 access to safe drinking water was 48 percent and had increased to 58 percent in 2006. Poor environmental sanitation is a major source of public health problems and epidemics in Zambia. Currently, over 80 percent of the health conditions presented at health institutions in Zambia are communicable diseases related to poor environmental sanitation, with significant adverse impact on the poor, especially children (Ibid).

2.26.4 National Decentralization Policy

The National Decentralization Policy is aimed at decentralizing government responsibilities and functions to lower levels of government through decentralization. It reaffirms the LAs as the institutions responsible for water supply and sanitation (MLGH, 2015a).

2.27 Legislation Under the Water Sector

2.27.1 National Environmental Action Plan

The focus of the National Environmental Action Plan (NEAP) is to identify environmental problems, analyze their causes, and recommend necessary interventions. NEAP is a comprehensive plan to contain the ever increasing environmental degradation in Zambia. It is based on three fundamental principles as follows: a) the right of citizens to a clean and healthy environment; b) local community and private sector participation in natural resources management and; c) obligatory EIA of major development projects in all sectors. Above all, the overall objective of the NEAP is to integrate environmental concerns into Zambia's social and economic development planning process (MLGH, 2015a).

2.27.2 Sixth National Development Plan

The Sixth National Development Plan (SNDP) contains a chapter on water and sanitation about all sectors such as agriculture, mining, industry, *housing* and energy which require access to adequate water and sanitation services for their development. The water and sanitation sector's vision is a "Zambia where all users have access to water and sanitation and utilize them in an efficient and sustainable manner for wealth creation and improved livelihood by 2030". The sector's goal is to achieve 75 percent accessibility to reliable safe water and 60 percent adequate sanitation by 2015 in order to enhance economic growth and improve the quality of life. In order to achieve the SNDP objective of promoting sustainable water resources development and sanitation, the strategic focus of the sector would be to provide water and sanitation infrastructure and develop skills to ensure effective water resource management and the efficient provision of reliable and safe water and sanitation services (World Bank, 2015).

2.28 Institutions Under the Water Sector

2.28.1 Ministry of Local Government

The MLG is the ministry most directly responsible for water supply and sanitation policy, technical and financial supervision as well as resource mobilization from foreign and local sources. The key functions undertaken by the MLG are urban planning and regional planning, including all water supply and sanitation issues. Whereas the DHID is located within the MLG and has the overall responsibility for planning, implementation, coordination and monitoring of water supply, sanitation and hygiene promotion. It provides policy guidance, technical and financial control and facilitates mobilization of foreign and local funds for water supply, sanitation and hygiene promotion (Ibid).

2.28.2 Ministry of Water Development, Sanitation and Environmental Protection

The MWDSEP is responsible for initiating overall national water management policies and for setting national standards and priorities for water development and management. In addition NWASCO is a statutory body established by the Water Supply and Sanitation Act. According to the Act, NWASCO is mandated to regulate the provision of water supply and sanitation services. NWASCO reports through the MWDSEP which keeps the regulatory function separate from the water and sanitation implementation function under the MLG. The following are the responsibilities carried out by NWASCO: a) developing policies regarding water and sanitation; b) setting standards and guidelines regarding water and sanitation; c) licensing water and sanitation utilities and monitoring their performance; and d) taking any necessary actions to ensure efficient and sustainable provision of water and sanitation services (NWASCO, 1997). Table 2.5 shows the standards for bacterialogical quality of drinking water.

Table 2.5: Standards for bacterialogical quality of drinking water

No	Type of water source	Organisms	Guideline values
1	All water intended for drinking	Echeria coliforms (*E. coli)*	Must not be detectable in 100ml of a sample of water
2	Untreated water	Echeria coliforms (*E. coli)*	Must not be detectable in 100ml of a sample of water
		Total coliforms	Must not be more than 10 in 100ml of a sample of water
3	Treated water entering the distribution system	Echeria coliforms (*E. coli)*	Must not be detectable in 100ml of a sample of water
		Total coliforms	Must not be detectable in 100ml of a sample of water

Table 2.5 continued

No	Type of water source	Organisms	Guideline values
4	Treated water in the distribution system	Echeria coliforms (*E. coli)*	Must not be detectable in 100ml of a sample of water
		Total coliforms	Must not be detected in any 100ml of a sample of water. In the case of large supplies, where sufficient samples are exammined, must not be present in 95 percent of samples taken throuhout any 12 month period.

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

2.28.3 Zambia Environmental Management Agency

ZEMA is a statutory body created under the Environmental Protection and Pollution Control Act. It is mandated to protect the environment and control pollution so as to provide for the health and safety of the householders and the environment. The act assigns to ZEMA roles and responsibilities, amongst which are the following: a) formulate and provide standards on the classification and analysis of wastes also advise on standard disposal methods and means; b) publicize the correct means of storage, collection and disposal of wastes; and c) maintain statistical data on the nature, quantity and volume of waste generated and on sites where waste disposal is taking place (ZEMA, 2011).

2.28.4 Lusaka City Council

The LCC is the governing local authority for the City of Lusaka, deriving its authority from several Zambian laws, mostly the Local Government Act. Some of the responsibilities of LCC include: a) provision and maintenance of supplies of clean water and the establishment of water works and water mains; b) construction and maintenance of sanitary lines; c) establishment and maintenance of sanitation and drainage systems to facilitate the removal of refuse and effluent; d) control the use of land and erection of buildings in the interest of public health, safely and orderly development of the Council area (MLGH, 2015a).

The two LCC departments most relevant to sanitation in the settlement areas are the City Planning Department and the Department of Housing and Social Services. Each department contains a peri-urban section; however, work sharing between the two sections is unclear (Ibid).

2.28.5 Lusaka Water and Sewerage Company Ltd.

The LWSC is the main water supply and sewerage service utility for Lusaka city. Its services were extended to Chongwe, Luangwa and Kafue District Councils in accordance with provisions of water supply and sanitation act no. 28 of 1997.It is regulated by NWASCO with the aim of improving the performance of water providers.(WSS, 1997) The LWSC owns and operates water supply and sewerage assets in Lusaka city and the aforementioned districts. In addition to the usual planning, engineering, construction, plant operations and maintenance functions, the LWSC also maintains a geographic information system (GIS), mapping capability, computer networks, instrumentation and control, and administrative functions for governance, management, human resources, service rates, collections, disbursements and finance (MLGH, 2015a). The current water demand for Lusaka city is around 560,000m^3/day and the water production is around 260,000m^3/day which is below the current demand and this indicates the challenges LWSC has in providing adequate water to its customers including upcoming settlements (Gauff, 2016)

2.29 Summary

The Literature on OWTS was reviewed in detail. Then, the physco-chemical and biological parameters leading to groundwater contamination and legal and regulatory framework and existing policies were discussed. Furthermore, the geology of Lusaka was reviewed. Then stakeholders in the water sector were identified and their roles discussed accordingly. Finally, literature on the study area was reviewed and gaps with respect to groundwater contamination levels and lack of enforcement on the part of authorities were identified.

CHAPTER 3 APPROACH AND METHODOLOGY

3.1 Introduction

This Chapter presents the approach and methodology which was used in this study. Initially, Literature was reviewed in detail with respect to groundwater contamination from septic tanks. Information and data available from scientific research reports and organizational reports available in Zambia were also reviewed. Then field observations were done in Meanwood- Kwamwena followed by structured interviews with key informants.

3.2 Research Design

The Research was descriptive in nature and used mixed methods (quantitative and qualitative) for data collection. The quantitative part of the study consisted of a survey using a questionnaire and the qualitative part used in-depth interviews with key informants. Then field observations which included laboratory testing of water for contamination were done in Meanwood-Kwamwena. The idea was to collect facts about various parameters on groundwater contamination from septic tank effluents. Document review was carried out based on scientific research reports, publications and reports from organizations in Zambia.

3.2.1 Sample Size

The sample size for the study area was 364 households, however due to limitation of resources a sample size of 13 households was drawn from a total population of 7100 This was based on the consideration of a worst scenario case of 50 percent of households not complying with set standards for mitigating groundwater contamination and a 95 percent confidence level with a 5 percent margin of error and a confidence interval of 27 percent. The sample size was determined using a website based sample size calculator from the website of The Survey System, Creative Research Systems (http://www.surveysystems.com/sscalc.htm).

3.2.2 Instruments / Tools

Questionnaires as shown in appendix G and interview guides as shown in appendix J were used in this study. The questionnaire was semi- structured with open ended questions. Also used was the 750 ml water bottle for collection of water samples for bacteriological testing as shown in appendix D, 50m Tape measure for measuring distances between boreholes and septic tank and dip stick for measuring depth of the septic tank. Geographic Information System (GIS) data was also obtained for the 13 sampling sites by using the GPSmap 60 and thereafter, a cartographic map of the sampled area was developed as shown in Figure 3.1.

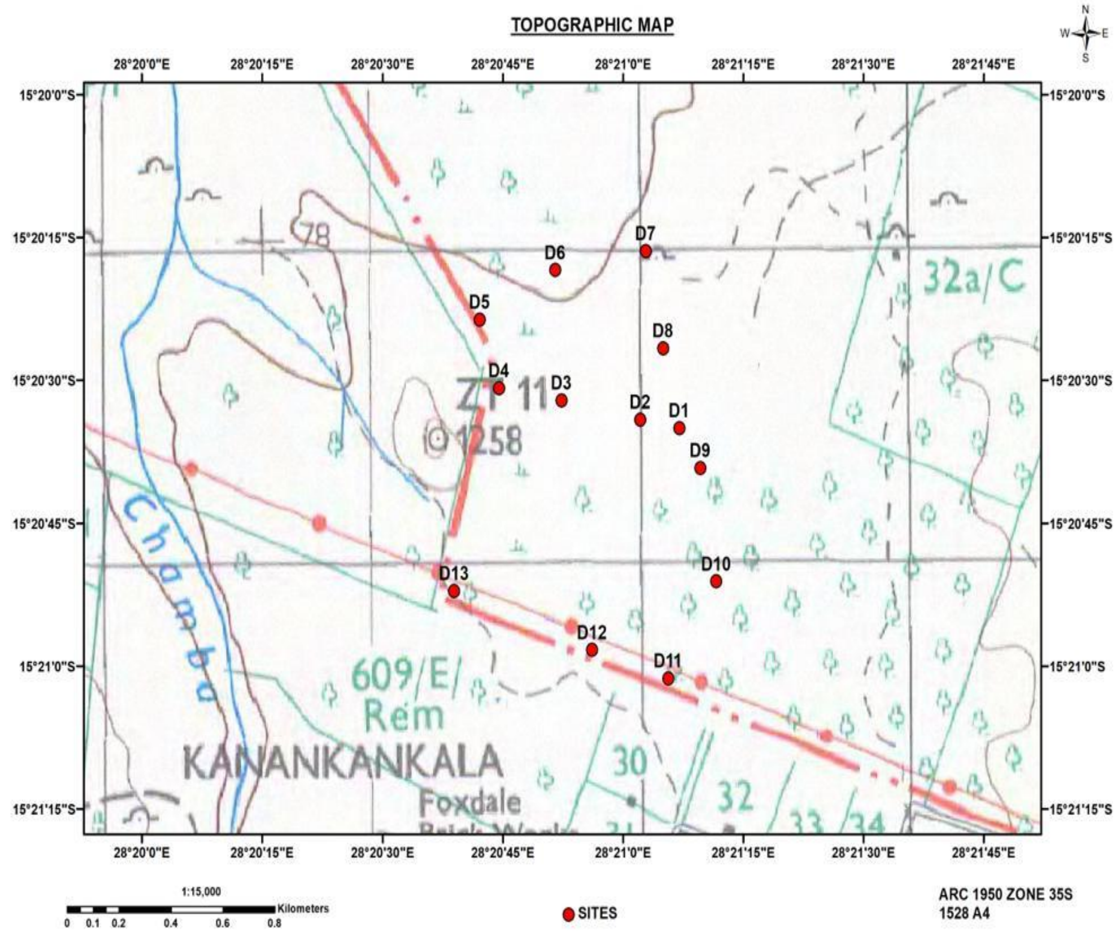

Figure 3.1: Topographic map and sampling sites of Meanwood- Kwamwena.

3.2.3 Data Collection Procedure

Data collection in this research study was done using documents from LWSC, LCC, ZEMA, MCC, GTZ, WARMA and WASAZA. Then, questionnaires were administered in the field to the 13 sampled households in order to obtain data about the use of septic tanks and boreholes in the household as shown in appendix G. Finally, structured interviews were conducted with key informants from NCC on septic tank design standards as shown in appendix F and interview guide in appendix J. These key informants were selected by the researcher based on their expertise and experience in the area of septic tank systems.

3.2.4 Sample and Sampling Size

A sample size of 13 households was drawn from a total population of 7100 households based on limitation of resources in data collection and analysis. A total of eight (8) questions were included in the questionnaire. The in depth interviews were conducted with three key informants who were selected purposely based on their in-depth knowledge about septic tanks. The key informants who were interviewed included three members of staff from NCC. The responses were collected, arranged, analyzed and filtered so that only useful responses were used.

3.3 Investigating the effects of septic tank effluents on household water quality

Investigating the effects of septic tank effluents on household water quality involved the knowledge of: 1) Approved septic tank design standards in Zambia; 2) water quality standards; 3) bacteriological examination of water; 4) distance from water source (borehole) to soakaway; 5) maintenance of septic tanks; 6) housing plot size.

Septic tank design standards were obtained from NCC; since NCC is mandated by law to provide the design standards. Thereafter, interviews on several households were conducted to find out on compliance to design standards, and maintenance of septic tanks. Housing plot sizes in Meanwood were further obtained from Chongwe Municipal Council to help ascertain septic tank concentration in the area. This was the case because each household depended on a septic tank and borehole as there was lack of services by utilities like LWSC.

Then, measurements of septic tank sizes were carried out from the 13sampled households within the study area using a 50 m measuring tape and a dip stick for obtaining the depth of septic tanks. Thereafter, the obtained depth of septic tanks were measured using a measuring tape after disinfecting the dip stick using chlorine solution. Finally, the length and width were also measured using the measuring tape and consequently the volume was computed using equation 3.1:

$$\boldsymbol{V = l * w * h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{Equation\ 3.1}$$

After determining septic tank volumes, comparisons were made with standard volumes as provided by NCC. Then distances between sources of water (borehole) and septic tank systems were also measured using a measuring tape and ultimately compared with the standard distance as provided by UNHCR, 2006. Water samples were then collected from the sampled household using sterilized 750 ml water bottles and immediately taken for testing of

Total coliforms and feacal coliforms at the Environmental Engineering Laboratory at the University of Zambia, School of Engineering – Department of Civil and Environmental Engineering.

3.4 Assessment of existing policies for mitigating the effects of septic tank effluents from households on water quality

The existing policies and regulations for mitigating impacts of groundwater quality were reviewed for the existing policies and regulations for mitigating impacts of groundwater quality. Firstly, this involved reviewing the global perspective and also a case for Zambia so as to carry out an assessment.

Global perspective: this involved relevant document review from UNHCR, WHO among others. Documents from organization which included WARMA, Millennium Challenge, GTZ were also studied.

Zambian scenario: Data was obtained from the following key organizations as a case for Zambia: LCC, NCC, ZEMA, LWSC, MCC, GTZ, and WASAZA. Being experts in this area, the aforementioned organizations were purposely selected by the researcher. This data and information was mainly in the form of documents and publications.

The data and information thus far obtained was further analyzed and an assessment on domestic groundwater quality based on septic tank effluent disposal was made. The baseline standards adopted in this study were based on WHO findings and documentations.

3.5 Design of a framework for mitigating effects of septic tank effluents

In developing a sound and cohesive integrated framework for mitigating effects of septic tank effluents, the following key issues were undertaken:

1. Knowledge of existing framework in Zambia.
2. Identification of stakeholders and their roles;
3. Funding management activities.

Then the framework for mitigating the effects of septic tank effluents on groundwater quality was designed based on the above key undertakings. These involved the inclusion of relevant stakeholders throughout framework development, the integration of scientific knowledge, data and analysis with risk assessment and management principles, and identification of the appropriate performance goals for successful management and mitigation of associated risks. These issues were addressed in the developing of a generic approach to assessing mitigating measures on septic tank effluents on groundwater quality.

3.6 Summary

This chapter presented the Methodology on key issues pertaining to investigations of effects of septic tank effluents on groundwater quality. Firstly, the research design was developed. Then the sample size to represent the total population was determined, after which tools for conducting the study were identified. Thereafter, the methods for data collection and analysis were presented followed by assessment of policies and designing of the framework on septic tank effluents on groundwater quality. The next chapter considers the Results of this study.

CHAPTER 4 RESULTS

4.1 Overview

This chapter presents the results in accordance with the objectives of this study based on the approach and methodology from chapter 3. It presents data collected from the study area. The initial data presented was a topographic map which highlighted the sampling sites and GIS data. Then data obtained through questionnaires from the respondents was presented. Finally, the process flow chart was developed from which the frame work for mitigating the effects of septic tank effluents from households on groundwater quality was developed.

4.2 Investigating the effects of septic tank effluents on household groundwater quality.

The first variable was number of occupants in each household.The results showed that the households with less than three (3) occupants were 7.7 percent, between four and six (4 - 6), occupants were 30.8 percent, between seven and nine (7 -9) was 53.8 percent and more than 10 occupants was 7.7 percent as shown in appendix I. The data on number of occupants in a household was required for use in determining the optimum size of the septic tank as shown in Figure 4.1.

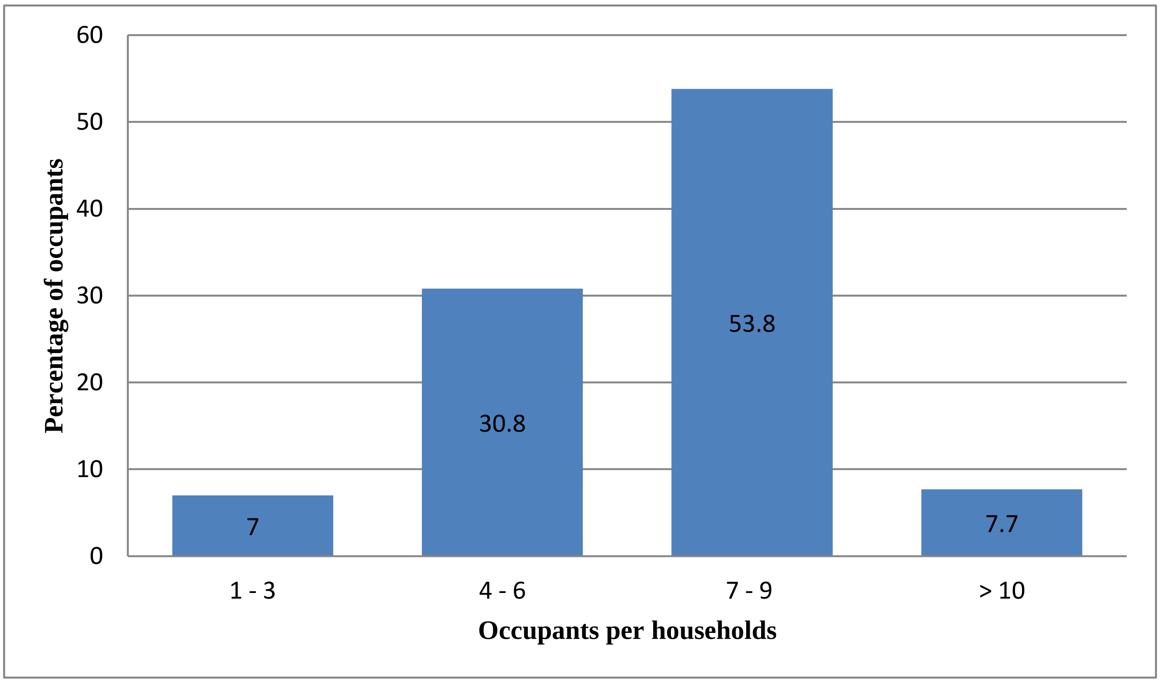

Figure 4.1: Number of occupants per household

The second variable was on awareness of design standards and the results showed that 38.5 percent of occupants were aware of the design standards whereas 61.5 percent were not aware of any design standard requirements as shown in appendix I. Implying that homeowners were constructing without any guidance to standards as shown in Figure 4.2.

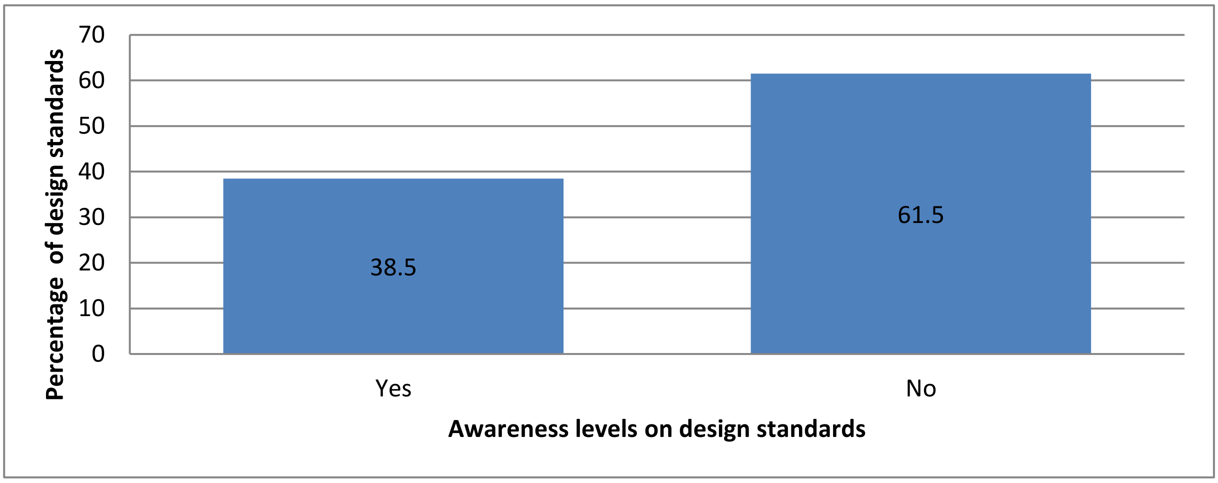

Figure 4.2: Awareness levels on design standards

The third variable was looking at sources of septic tank design standards. From appendix I, those who obtained designs from the council were 7.7 percent, from other sources were 69.2 percent and those not sure of the source were 23.1 percent. The others who were represented by 69.2 percent indicated sources such as private architects and droughsmen and bricklayers advise. While the 23.1 percent who were not sure of the source indicated that they osberved from their neibours and just general knowledge about septic tank construction. Figure 4.3 shows the sources of septic tank design standards and corresponding percetanges of responses.

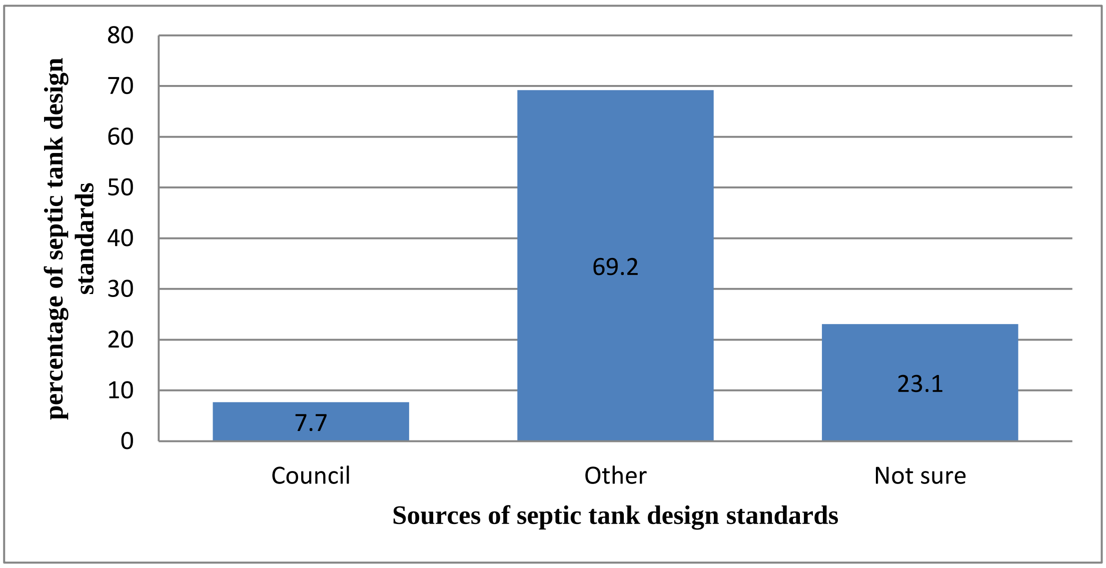

Figure 4.3: Sources of septic tank design standards

The fourth varible looked at the frequency of pumping out sludge from a septic tank as shown in appendix I. 76.9 percent indicated that they never pumped out since they constructed the septic tanks. Then pumping out between two to three (2 - 3) years and more than three (3) years ago was 0 percent as shown in Figure 4.4. Further, 23.1 percent were not aware of having to pump out the septic tank because they perceived that once a septic tank is constructed, there is no need of maintenance.

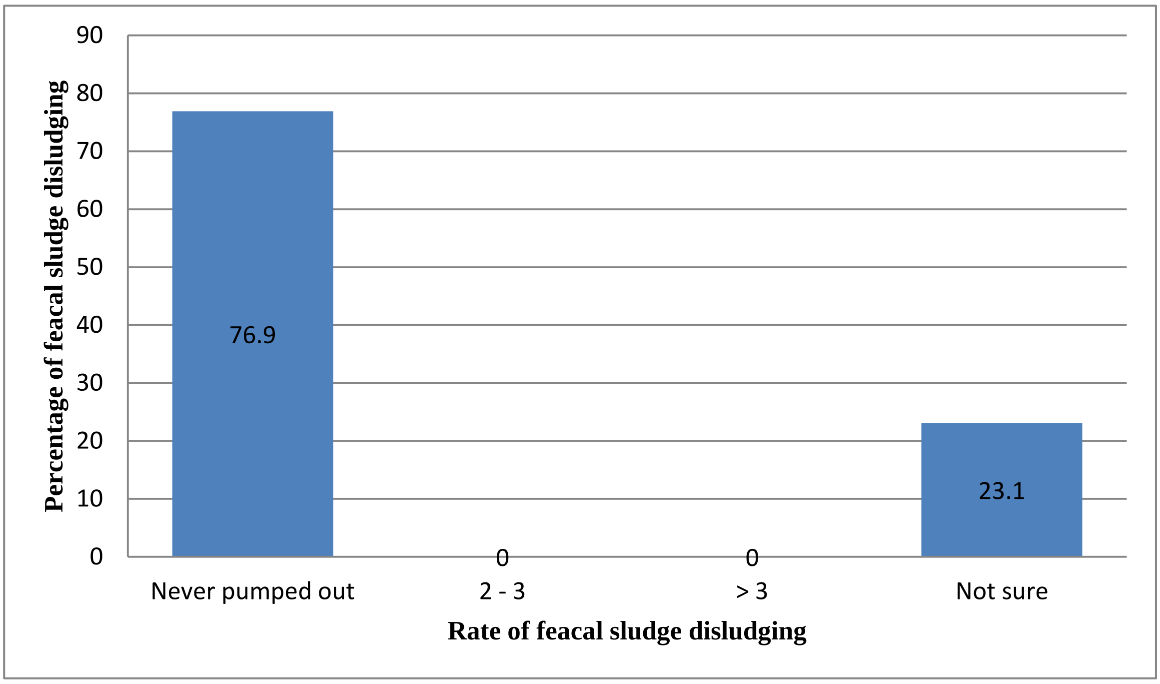

Figure 4.4: Rate of feacal sludge disludging

The fifth variable looked at awareness of a standard for minimum distance between borehole and septic tank. Those who were aware of the requirement of a minimum distance between borehole and septic tank were 30.8 percent whereas those who were not aware were 69.2 percent as shown in appendix I. The reasons were lack of knowledge of the existance of this standard. Figure 4.5 shows the awareness of minimum distance between septic tank and borehole and corresponding percentages of responses.

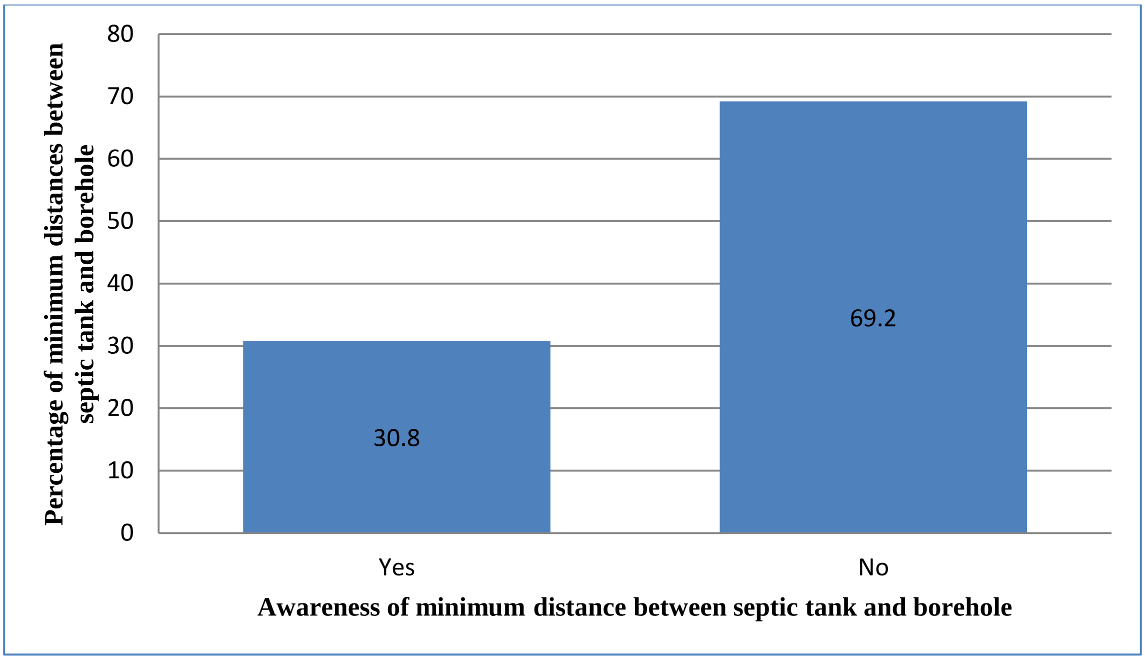

Figure 4.5: Awareness of minimum distance between septic tank and borehole

The sixth variable looked at awereness of groundwater contamination from poorly constructed septic tanks. 38.5 percent were aware of groundwater contamination from poorly constructed septic tanks whereas 61.5 percent were not aware as shown in appendix I. The main reason being lack of knowledge on groundwater contamination with respect to septic tanks. The general perception was that a septic tank was safe and could not cause contamination. Figure 4.6 Shows the Awareness of groundwater contamination from poorly constructed septic tanks and corresponding percentages of responses.

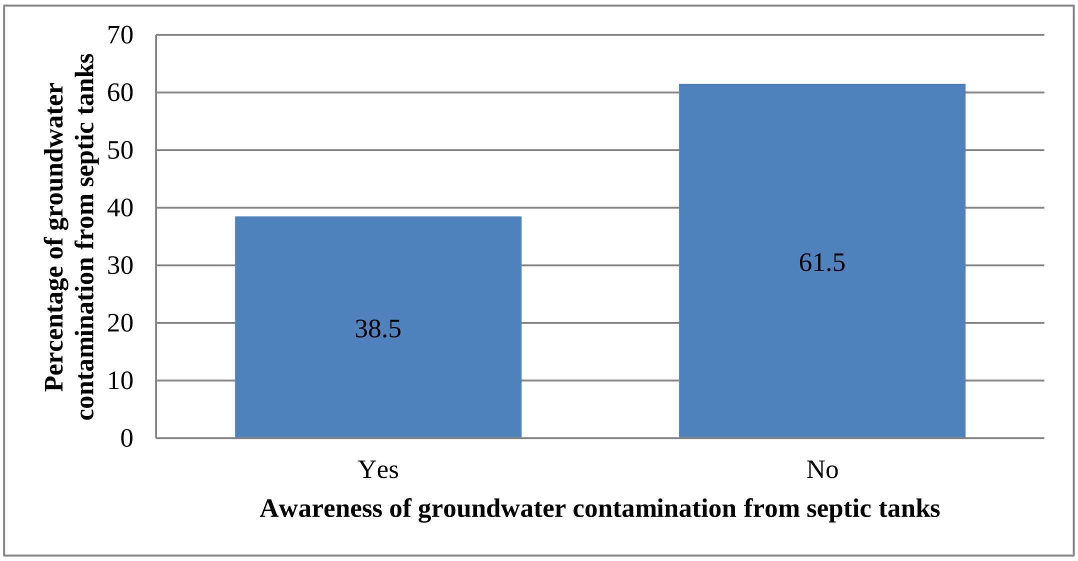

Figure 4.6: Awareness of groundwater contamination from poorly constructed septic tanks.

The seventh variable looked at the frequency of testing borehole water for contamination. From the results those who tested every six months were 23.1 percent, every 12 months was 7.7 percent, more than 2 years was 23.1 percent and those who never tested was 46.1 percent as shown in Appendix I. The 46.1 percent who never tested the water for contamination were of the perception that the borehole water was safe for drinking. Figure 4.7 shows the frequency of testing borehole water for contamination and the corresponding percentages of responses.

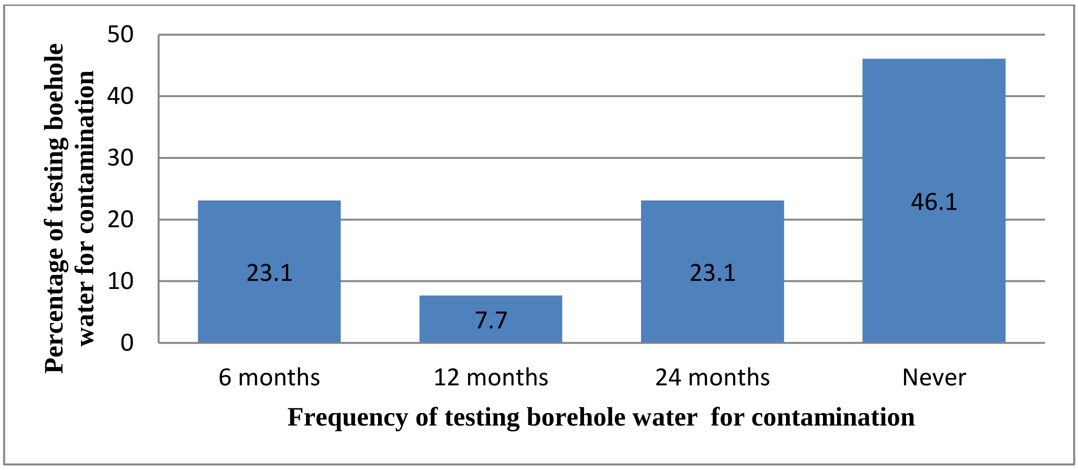

Figure 4.7: Frequency of testing borehole water for contamination

4.2.1 Model development

$$V = 0.338N + 3.54 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{Equation\ 4.1}$$

Using the datafrom NCC, the model shown in equation 4.1 was developed.The model was then used to determine the baseline data for the septic tank size as shown in table 4.3.

Table 4.1 compares Field Data with Baseline Data. Field Data shows the number of occupants in each of the 13 households with the corresponding septic tank sizes for both field and baseline data.

Table 4.1: Baseline septic tank sizes against field data (based on number of occupants and the corresponding septic tank size).

SNº	FIELD DATA		BASELINE DATA
	NUMBER OF OCCUPANTS	SEPTIC TANK SIZE[m^3]	SEPTIC TANK SIZE[m^3]
1	6	7.5	5.6
2	8	9.0	6.3

Table 4.1 continued

SNº	NUMBER OF OCCUPANTS	SEPTIC TANK SIZE [m^3]	SEPTIC TANK SIZE [m^3]
3	11	10.8	7.3
4	5	6.8	5.2
5	7	12.6	5.9
6	9	11.3	6.6
7	8	18.8	6.3
8	7	15.0	5.9
9	4	9.9	4.9
10	8	11.3	6.3
11	8	8.1	6.3
12	6	9.0	5.6
13	3	8.1	6.3

Figure 4.8 Compares septic tank sizes with field and baseline data in form of a bar chart. The data showed that the tank sizes from the field are larger than baseline data.

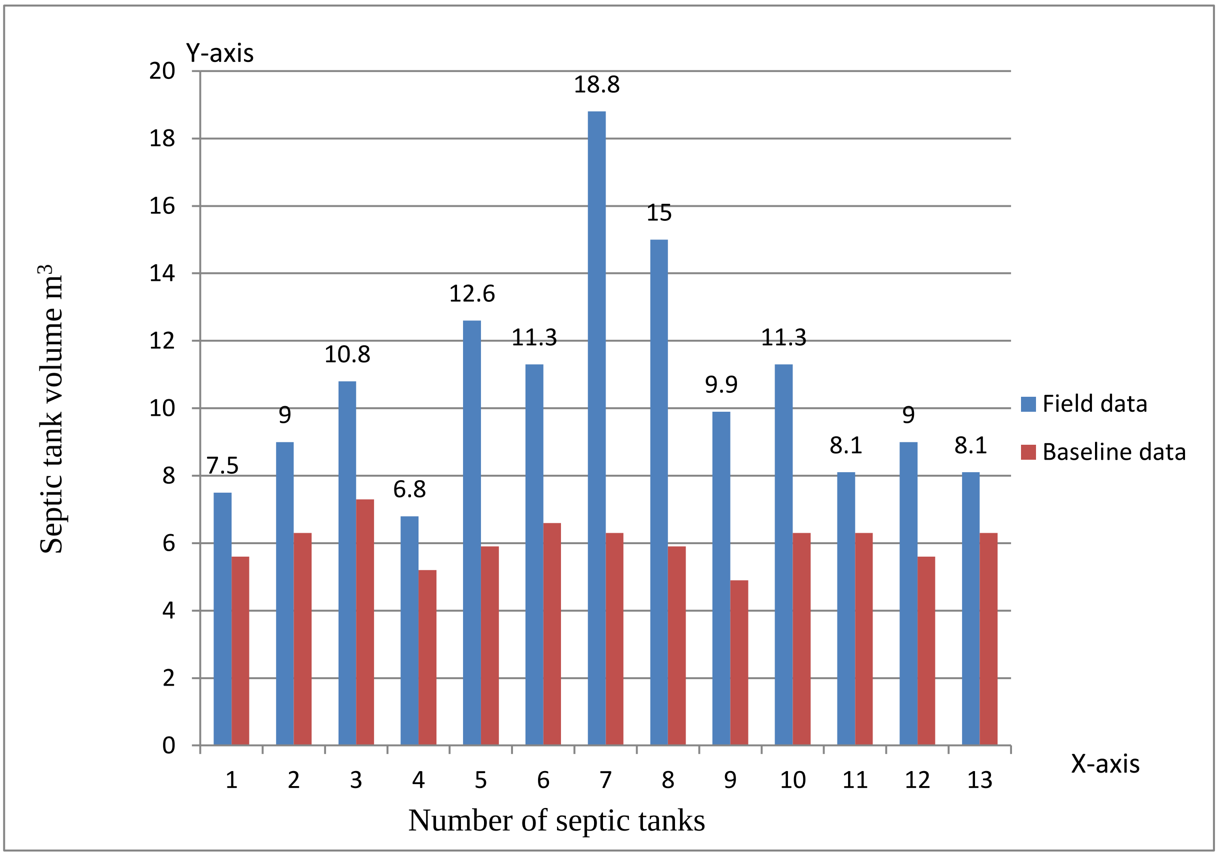

Figure 4.8: Comparing field data to baseline data (septic tank sizes, m^3)

Table 4.2 shows plot sizes and the average distances (field data) between borehole and septic tank with the corresponding standard of a minimum of 30m as specified by UNHCR. The table further shows that, plot sizes of 20*20 had an average distance between borehore and septic tank of 16.4 m, then plot sizes of 25*20 had an average distance of 18.2 m whereas the 30*30 plot sizes had an average distance of 24.3 m.

Table 4.2: Plot sizes and distances between borehole and septic tank

SNº	PLOT SIZE (m)	FIELD RESULTS (Average Distances) (m)	BASELINE DISTANCES (m)
1	20*20	16.4	30
2	25*20	18.2	30
3	30*30	24.3	30

Table 4.3 shows results for the bacterialogical examination of water from the 13 sampled households.The tests carried out involved two parameters i.e. Total Coliforms and Feacal coliforms. From the table, 5 households were found to be contaminated with both Total Coliform and Feacal Coliform out of the 13 households.

Table 4.3: Bacterialogical examination of water

SAMPLE ID	TOTAL COLIFORMS (#/100mml)	Feacal coliforms (#/100ml)
Household No. 1	25	15
Household No. 2	TNTC	TNTC
Household No. 3	0	0
Household No. 4	0	0
Household No. 5	TNTC	TNTC
Household No. 6	0	0
Household No. 7	0	0
Household No. 8	0	0
Household No. 9	TNTC	8
Household No. 10	TNTC	TNTC
Household No. 11	0	0
Household No. 12	0	0
Household No. 13	0	0

4.3 Assessment of existing policies for mitigating the effects of septic tank effluents from households on water quality.

Table 4.4: Some of the existing policies in *Zambia* concerned with the use of resources of which groundwater is part.

S/N	Policy	Mandate
1	National Water Policy	The National Water Policy is aimed at promoting a sustainable water resource development with a view to facilitate an equitable provision of adequate quantity and ***quality*** of water.
2	National Policy on Environment	This policy was developed to avoid conflict of interest, harmonise sectoral strategies and rationalise legislation that concerns the use and management of environment in order to attain an integrated approach to development through a national cross cutting consensus It was designed to create a comprehensive framework for effective natural resource utilization and environmental conservation thereby sustainable development.
3	National Health Policy	The National Health Policy outlines a statement by GRZ to set clear directions for the development of the health sector in Zambia. The policy in anchored in the vision 2030 and is being implemented through successive National Development plans and National Health strategic plans.

Table 4.5: Some of the existing policies – a *global* perspective

S/N	Existing Policy	Mandate
1	National Water Policy for Netherlands	This policy is incorporated in the National Water plan for 2016-2021 with a preview towards 2050. The national water plan is a robust and future –oriented design of the water system aimed at protection against floods and achieving good *water quality* and a healthy ecosystem as the basis for welfare and prosperity. Water policy management in the Netherlands is the joint responsibility of the government, provinces, municipalities and water boards. Water policy is formulated and implemented according to the catchment area approach. The various water challenges are considered within a natural and geographical unit with administrative boundaries being of secondary importance.
2	National Policy for the Protection of Groundwater in UK	The national policy is based on the concept of groundwater vulnerability in order that the greatest protection is given to those most at risk. Control is exercised through a combination of legal requirements, statutory and non statutory codes of practice, published policy and guidance documents together with general advise
3	Groundwater Protection Policy for Scotland	The national legislation requires that pollution must be prevented and that groundwater resources are managed in a sustainable way. This policy aims to provide sustainable future for Scotland's groundwater resources by protecting legitimate uses of groundwater resources and providing a common SEPA framework to: Protect groundwater quality by minimising the risks posed by point and diffuse sources of pollution, Maintain groundwater resource by authorising abstractions and by influencing developments which could affect groundwater quantity (SEPA, 2004).

Table 4.5 continued

S/N	Existing Policy	Mandate
4	Policy for Groundwater Protection- European Union.	The EU water policy has been based on six basic principles: high level of protection of groundwater resource, application of the precautionary (prevention) principle, the prevention of pollution, the rectification of pollution at source, the application of the polluter pays principle, and the integration of environmental protection into other policies such as agriculture, transport and energy. The policy was further revised to expand the scope of water protection to all waters i.e. surface water and groundwater. The main features of the policy include the recognition that underground water plays a part in maintaining a sustainable ecosystem and drinking water supply and that water quantity and quality are inter linked. The policy demands forward planning through the development and publishing of river basin management plans with involvement of stakeholders (WHO, 2006).

4.4 Framework for mitigating effects of septic tank effluents

Figure 4.9 shows the process flow chart for mitigating the effects of septic tank effluents from households. MLG, MOH and MWDSEP are the policy formulators and NWASCO, ZEMA, WARMA, MOH and LAs are the regulators. If policy is appropriate, then the regulators instruct Developers to construct septic tanks accordingly, and if not then the policy goes back for formulation. Once the developers construct, the inspectors from the LAs inspect and certify if construction is according to standard and if not the developer will be required to redo the construction. Hence ultimately this would ensure safe disposal of effluents from households.

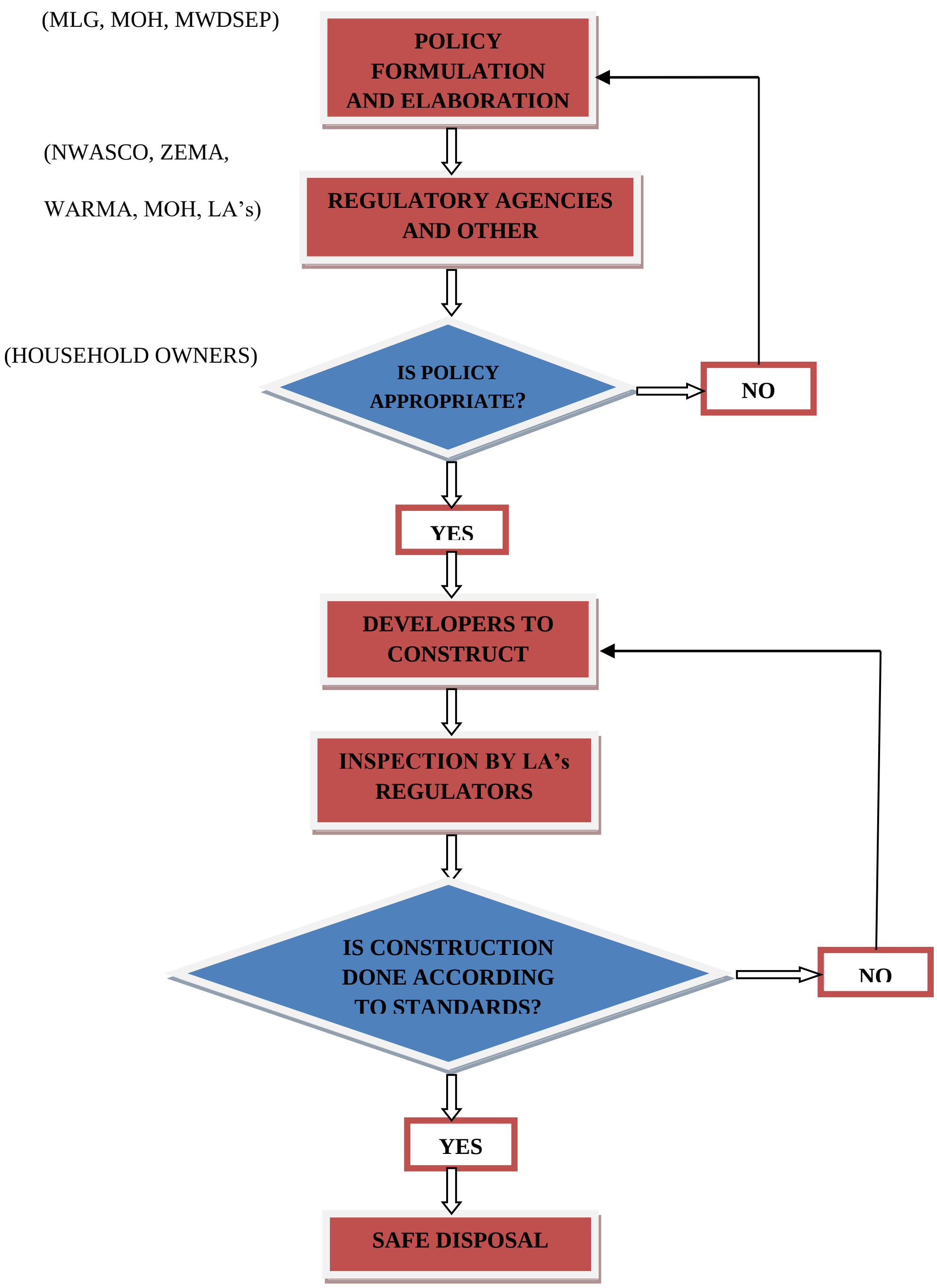

Figure 4.9: Process flow chart for mitigating effects of septic tank effluents

Figure 4.10 shows the developed framework for mitigating groundwater contamination from effects of septic tank effluents from households.The framework shows three stages of monitoring and control. The figure shows policy formulation and elaboration, regulatory agencies and developers.

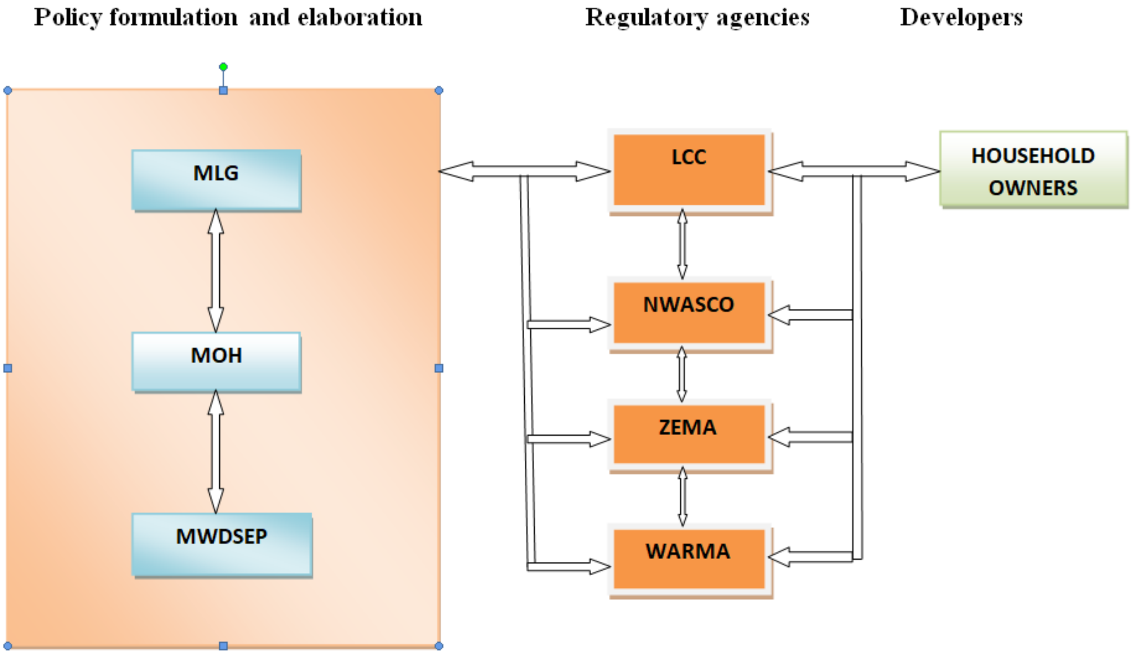

Figure 4.10 Framework for mitigating the effects of septic tank effluents

4.5 Summary

This Chapter presented the results of the study. Field results were highlighted and shown on the topographic map and GIS data.Then the responses from the questionaires were analysed and generally revealed the lack of knowledge by developers on septic tank design standards and lack of guidance and enforcement from local authorities on adherence to standards. Bacterialogical examination of water showed that 5 out of 13 households were contaminated with feacal coliforms and Total coliforms. Then, the Design of a framework for mitigating the effects of septic tank effluents from households on groundwater quality was developed.

CHAPTER 5 DISCUSSION

5.1 Introduction

This chapter discusses the results which were presented in chapter four. The discussion was guided by the research objectives as follows:

5.2 Investigating the effects of septic tank effluents on household water quality

In this research work, the first objective was to investigate effects of septic tank effluents on groundwater quality. This involved field survey and finding the appropriate sample size to represent the total population and then an investigation on parameters such as plot sizes and distances between borehole and septic tanks, septic tank volume determination, model development, and bacterialogical exammination of water were done.

Figure 3.1 shows the topographic map of the study area which is Meanwood Kwamwena. The 13 households which were sampled have been highlighted in Figure 3.1. Appendix H shows the sampling sites, elevations, coordinates and description of the areas where the households are located.

From the literature reviewed and Figures 4.2 and 4.5, the results showed that households sampled did not comply to Standard construction designs from LAs and the requirement of minimum distances between boreholes and septic tanks of 30 m as stipulated by UNHCR.. Also on awareness of design standards, the results showed that 38.5 percent of households were aware and 61.5 percent were not aware of design standards indicating that the majority of households constructed septic tanks without any guidance on standards. On Maintenance of septic tanks as shown in Figure 4, the results showed that 76.9 percent of occupants never pumped out sludge ever since they constructed the septic tanks and 23.1 percent were not aware on the need to pump out. This also was attributed to lack of knowledge because they perceived that once a septic tank was constructed, there was no need of maintenance.

Most householders, did not show concern over maintenance aspects of the septic tank systems e.g disludging. Some of the reasons as to why this was so were due to 1) financial capacity, 2) lack of awareness and, 3) lack of enforcement by LA's and other concerned stakeholders. This parameter exposed the fact that household owners need to be made aware of maintenance aspects of septic tanks.

In general the indication from the results is that household owners lack knowledge on the existance of Design Standards of septic tanks, Groundwater Contamination from septic tanks and on the importance of testing the borehole water for contamination as shown in Figures 4.5, 4.6 and 4.7.

Table 4.1 showed the number of occupants per household against septic tank sizes for field and baseline data. Baseline data was obtained from NCC as shown in Appendix F. Then the baseline data was used to develop a model as shown by equation 4.1.

Also, Table 4.1 showed for the same number of occupants, field data and baseline data for septic tank volumes. It was further observed that all field septic tank sizes were larger than baseline ones (Figure 4.2) e.g for 6 occupants per household, field data for septic tank size was 7.5 m^3 whereas for baseline septic tank size was 5.6 m^3 giving a variance of 33.9 percent. The larger sizes of septic tanks were partly due to the fact that developers constructed septic tanks based on the available space, financial capacity of the householder and on advice from unskilled bricklayers (builders) who have limited or no knowledge of design and construction of septic tank systemes. The other reason for oversizing septic tanks was that developers wanted a septic tank which is generally maintenance free i.e. no disludging for a very long period of time.

Plot sizes in the study area were found to be a limiting factor on distances between boreholes and septic tanks. From Table 4.2, thus, the above field results showed that distances between boreholes and septic tanks were all less than the required minimum of 30 m. From this, it was clear that plot size had a corresponding effect on distance between borehole and septic tank i.e. the smaller the plot size, the less the distance between borehole and septic tank and vice versa. Therefore, plot sizes in an area where boreholes and septic tanks systems are to be considered, relevant stakeholders (e.g. LAs etc) must provide a minimum plot size which could accommodate a minimum distance between borehole and septic tank of 30 m. Further, the LAs must provide guidance to developers to ensure that the minimum requirements are met. Or else there should be no septic tanks development or standardized communal septic tank systems to be developed under the guidance of the LA's.

From the 13 households sampled for bacterialogical examination of water, it was found that 61.5 percent were satisfactory (not contaminated) whereas 38.5 percent were unsatisfactory (contaminated) as shown in Table 4.3 and Appendix D. The contaminated boreholes were those located down slope at lower elevation and might be the cause of the 38.5 percent contamination while those which were not contaminated were those on the Western side which are up slope at higher elevation. According to Waller, (2016) the sewage can discharge through leach lines located at higher elevations and could raise the groundwater level and flood leach fields at lower elevations

According to WHO standards, groundwater on the Western side was also supposed to be contaminated since distances between boreholes and septic tanks were less than the required 30 m as shown in table 4.2. However, the groundwater was not yet polluted since the settlement area was relatively new. In that case, It could be justified to say that contamination would eventually take place as the settlement gets relatively older since the septic tanks would accumulate sludge and start discharging raw septage into the ground. Also according to US EPA (2015), it is exepected that the groundwater quality will detoriate because the boreholes are located in close proximity to septic tanks which are prone to groundwater pollution.

Appendice A, B, and C show the septic tank system water discharge, leaking septic tank, and three typical diagrams -: drainfield, hillslope, and watershed. The diagrams help illustrate the aspect of the interaction between the septic tank effluents and groundwater.

Appendix E shows the letter of publication from journal of Natural and Applied Sciences as proof of publication.

5.3 Assessment of existing policies for mitigating the effects of septic tank effluents from households on groundwater quality

From table 4.9 it was shown that Zambia has policies among others, National water policy, National policy on environment and national health policy. At global level the following policies were reviewed as shown in table 4.10 as follows: National water policy for Netherlands, National policy for the protection of groundwater in UK, Groundwater protection policy for Scotland and Policy for groundwater protection in the European Union.

The National Water Policy was developed with the view of promoting a sustainable water resource development to facilitate an equitable provision of adequate quantity and quality of water. This was to be achieved by vesting ownership of water resources in the country under the state control and defining clear institutional responsibilities of all stakeholders in the water sector for effective management and coordination. This demonstrates that Zambia has a water policy in place and what is required is implementation which should be applied.

National Policy on Environment provides overall guidance on environmental and natural resource management, including the requirement to make public the Environmental Impact

Assessment (EIA).This policy emphases on the duties of government, institution and community to exercise proper control and care of the environment. Also this demonstrates that the country has a national policy on environment in place however there is need to strengthen and emphasize the stakeholder involvement in mitigating groundwater quality management. This is so because groundwater can be contaminated from various factors such as land use, concentration of septic tanks in an area, improper management and construction of septic tanks. Hence involvement of relevant stakeholders and cooperation among them is essential in mitigating groundwater contamination.

The national health policy main objective is to ensure equitable access to primary health care services for all the population regardless of the social , economic and geographical status and to comply with the WHO recommendations on social determinants for health. However, the health sector faces a lot of challenges including inadequate funding, shortage of health workers etc. This negatively impacts on the health sector to fulfill their duties hence need to increase resources to the sector.

The National Water Policy for Netherlands main objective is protection against floods and achieving good water quality and a healthy ecosystem as the basis for welfare and prosperity. The water policy for Netherlands compared with the water policy for Zambia, both are addressing the specific needs for their countries and are future oriented. The major factor is the enforcement of the implementation so as to realize the objectives of the policy in place.

National policy for the protection of groundwater in UK, The national policy is based on the concept of groundwater vulnerability in order that the greatest protection is given to those most at risk. Comparison of the UK groundwater policy with the water policy in Zambia, it is clear that Zambia has no policy specifically for protection of groundwater. What is there is groundwater is included in the general water policy. Nevertheless, the important factor is that the policy is in place.

Groundwater protection policy for Scotland This policy aims to provide sustainable future for Scotland's groundwater resources by protecting legitimate uses of groundwater resources and providing a common SEPA framework. This policy focuses on mitigation of groundwater contamination and this has been implemented by putting in place prevention measures which include the proper control of effluents from OWTS.

Policy for groundwater protection in the European Union main objectives is the recognition that underground water plays a part in maintaining a stable ecosystem and drinking water supply and that water quantity and quality are interlinked. This policy has combined perspectives of quantity and quality management in decision making hence an integrated approach in mitigation of groundwater contamination.

5.4 Design of a framework for mitigating effects of septic tank effluents

Figure 4.9 shows a process flow chart which helped in developing a framework for mitigating effects of septic tank efluents as shown in figure 4.10. The purpose of the framework was to render consistency of outcomes and also serve as a guiding principle for mitigating effects of septic tank effluents on groundwater quality. Firstly, policy formulation was addressed which was intended to serve as a strategy or plan as part of the structure with respect to mitigating effects of septic tank effluents. In this context, Policy formulation is the development of effective and acceptable courses of action for addressing what has been placed on the policy agenda as described by Hayes (2014).

In the case for Meanwood-Kwamwena, the MLG, MWDSEP and the MOH could be responsible for policy formulation and elaboration. The three entities are critical in this scenario since the MLG would look into issues of land and its allocation with set standards in line with mitigating effects of septic tank effluents on groundwater quality. The MWDSEP and MLG are key players in policy formulation, planning and co-ordination in respect of environmental health matters as reflected in the Environmental Protection and Pollution Control Act Cap. 204. The MLG is mandated to carry out the decentralization process, i.e. handing over powers of management and administration to the local authorities. The Department of Water Affairs, administers the National Water and Sanitation Act No. 28 of 1997 that establishes the National Water Supply and Sanitation Council (NWASCO). The Council's mandate provides for establishment of water supply and sanitation utilities. MLG also gives LA's responsibilities to provide water and sanitation within areas of their jurisdiction. Its Act, supports measures to prevent pollution of supplies of water. It is also responsible for the development and provision of plans, standards, designs and construction of septic tanks. However, findings revealed that, despite good policies in place, implementation was a challenge as the LA's have been faced with several challenges such as population increase due to urbanization and lack of finances for capital projects. This leads to a situation where unsuitable areas are allocated for settlement e.g. wet lands, and areas prone to flooding etc, henceforth, groundwater contamination.

The findings also brought out some issues which make the LA's under-perform. These were: lack of capacity, which included 1) inadequate funding as councils were grappling with a lot of financial challenges; 2). Lack of equipment e.g. vacuum tanks.

MOH is a ministry responsible for the health policy formulation and is a major player in policy formulation, planning and co-ordination in respect of environmental health matters. Cap 303 of the Laws of Zambia empowers the authorized officers (Medical officers and health inspectors) to control the environmental health standards of general premises, including housing. However, this function is poorly carried out due to inadequate financing on environmental health related programs and lack of compliance to environmental health standards pertaining to sanitary facilities. Poor co-ordination of stakeholders that are responsible for promoting and protecting environmental health has compounded the problem of contamination of groundwater in this particular case.i.e. poor work culture within the organisations and complicated organisational structures which contributed to lack of enforcement of legal standards. Hence the need to adopt the simplified framework which has been designed in this study as shown in figure 4.10. This framework could help policy makers to develop good strategies because of its simplicity and ease of implementation which would lead to mitigation of groundwater contamination.

The Government agencies with capacities tasked to carry out environmental inspections that ensure maintenance of environmental standards, have not performed to expectation due to a wide range of constraints, which include: lack of capacity in legal prosecution, field transport and financial resources.

As seen in table 4.3, bacterialogical tests for water samples showed the presence of feacal coliforms and Total coliforms which are dangerous to human health; hence the critical role of the Ministry of Health in policy formulation and elaboration. The presence of feacal coliforms is directly as a result of feacal matter emating from septic tanks which could be leaking or poorly maintained ending up in poor treatment of the septic tank effluents.

To provide order and control, regulation and advisory is required. This responsibility must be undertaken by NWASCO, ZEMA, WARMA, LAs and MOH. These entities must act where normalization, adjustment and standardization is needed as mandated by law. In that case developers or household owners must comply with the correct standards and procedures in which case mitigation would be attained. Where compliance is lacking, regulatory entities must advise and developers must ensure corrective measures. If this structure is adhered to, mitigating effects of septic tank effluents on groundwater quality would be attained.

5.5 SUMMARY

This chapter discussed the results which were presented in accordance with the objectives. Firstly an investigation on parameters such as plot size, distance between borehole and septic tank, septic tank volume compared with baseline data and bactrialogical exermination of water were considered. Secondly an assessment of existing policies for zambia and the global perspective were assessed. The third objective was to Design a framework for mitigating the effects of septic tank effluents which involved the development of a process flow chart from which the frame work was designed.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This chapter presents the Conclusions of this study. Recommendations for the future work are also made thereafter. In accordance with the research objectives of this work, the following conclusions were made:

1) Plot sizes were a limiting factor to distance between borehole and septic tank (and was found to be < 30m i.e. less than the minimum required distance); meaning that the 62.5 percent of the sampled households not contaminated had their septic tanks oversized. Thus, not filled up yet as the area is relatively new. However, 38.5 percent of boreholes which were found to be contaminated with Feacal coliforms and Total coliforms were those boreholes which are located in close proximity to septic tanks and are at lower elevation.
2) Despite the existence of policies and guidelines for constructions and designs of septic tank systems in relation to boreholes and septic tank distances, compliance was non-existence and also enforcement by the relevant authorities was lacking.

3) For enhanced mitigation of groundwater contamination it is imperative that all stakeholders in the water sector start coordinating and convening meetings in order to achieve the objectives of mitigation of groundwater contamination.

6.2 Recommendations

i. All stakeholders must be collaborating and convening of stakeholder groups when it comes to creation of settlements and protecting groundwater quality e.g. MOH, MLG, WARMA, LWSC, LAs etc. This would enable stakeholders to analyze growth, development and future risk and addressing of prevailing gaps.
ii. Capacity building of staff to have the necessary competencies which would enable them perform their duties effectively.
iii. Public awareness on the existence of standards based on septic tank systems with respect to groundwater contamination should be Government's responsibility.
iv. Regulatory bodies must be adequately funded as they are currently underfunded; which contributes to the bodies/agencies being incapacitated.
v. Introduction of a fee to household owners who have developed septic tanks so as to enable regulatory bodies raise the monetary resource to carry out regular inspections of septic tanks to ensure compliance and long term health benefits.

vi. Government must:

- Ensure that there is regular monitoring of water sources in accordance with the relevant regulations.
- Make sure that set standards for groundwater quality intended especially for domestic use are adhered to.
- Ensure that the geological and hydrogeolical studies have been udertaken, suitable locations have been identified, and a qualified contractor to conduct hydro-geological investigations (test drilling) have been identified before any borehole is drilled.

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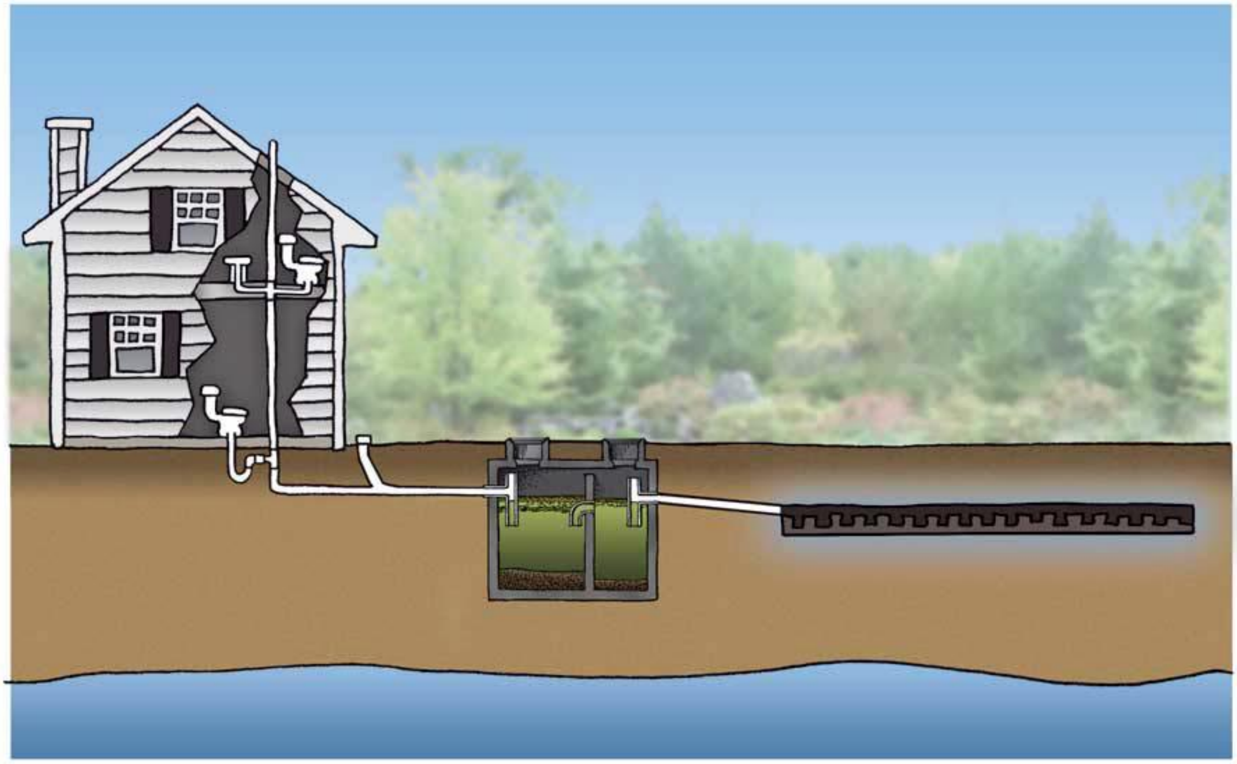
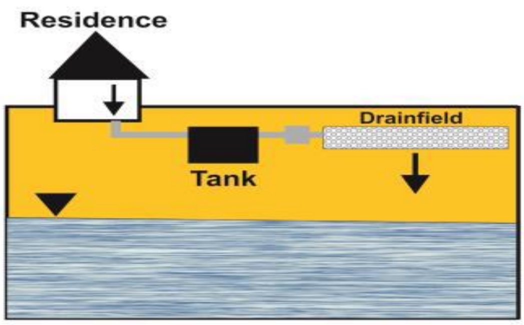
APPENDICES

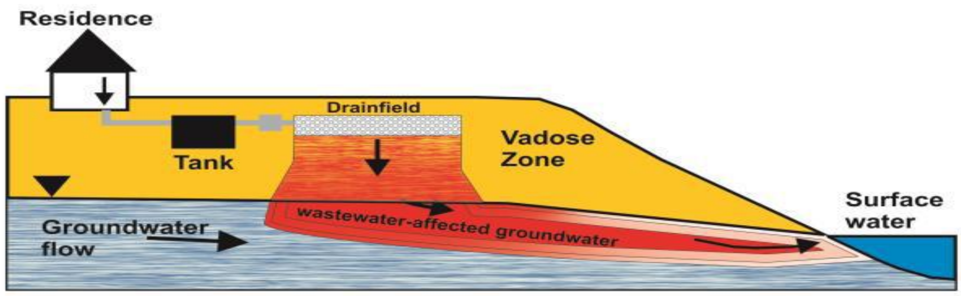
APPENDIX A: SEPTIC TANK SYSTEM WASTE-WATER DISCHARGE



APPENDIX B: LEAKING SEPTIC TANK HAS THE POTENTIAL TO AFFECT GROUND WATER QUALITY

APPENDIX C: TYPICAL DIAGRAMS SHOWING DRAINFIELD, HILLSLOPE, AND A WATERSHED





APPENDIX D: BACTRIALOGICAL EXAMMINATION OF WATER – UNZA ENVIRONMENTAL LABORATORY

SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT
ENVIRONMENTAL ENGINEERING LABORATORY

P.O Box 32379, Lusaka
Direct Telefax: 260-1-290962
Telegram: UNZA LUSAKA
Telex: ZA44370

BACTERIOLOGICAL EXAMINATION OF WATER

Attn : Francis Daka
Lusaka
Sampled by : Client
Sampling date : 21.06.2018
Report date : 22.06.2018

Laboratory Results

Sample ID	Total coliforms (#/100ml)	Feacal coliforms (#/100ml)
House N0.1	25	15
House N0.2	TNTC	TNTC
House N0.3	0	0
House N0.4	0	0
House N0.5	TNTC	TNTC
House N0.6	0	0
House N0.7	0	0
House N0.8	0	0
House N0.9	TNTC	8
House N0.10	TNTC	TNTC
House N0.11	0	0
House N0.12	0	0
House N0.13	0	0

Tests carried out in conformity with " Standard Methods for the Examination of water and Wastewater APHA, 1998".

TNTC: Too Numerous To Count
Comment: On the day of sampling the bacteriological quality of the water was bad at House No. 1,2,5,9 and 10. The water needs to be treated before drinking (i.e. Boiled, Chlorinated or UV treated)

J. Kabika
Co-ordinator- Environmental Engineering Laboratory

UNIVERSITY OF ZAMBIA
SCHOOL ENGINEERING
22 JUN 2018
CIVIL AND ENVIRONMENTAL
ENGINEERING LABORATORY
P.O. BOX 32379, LUSAKA.

APPENDIX E: LETTER OF PUBLICATION FROM JOURNAS

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

Telephone: +260 - 211 - 290258/293937
Fax: + 260- 211- 290258/293937
Email: drgs@unza.zm

P O Box 32379
Lusaka
ZAMBIA

24th January, 2019

Mr. Francis Dabwitso Daka
C/o The University of Zambia
School of Engineering
Department of Civil Engineering
P.O. Box 32379
LUSAKA

Dear Mr. Daka,

RE: SUBMISSION OF ARTICLE FOR POSSIBLE PUBLICATION IN THE JOURNAL OF NATURAL AND APPLIED SCIENCES

On behalf of the Editorial Board of the Journal of Natural and Applied Sciences, I wish to acknowledge receipt of your two manuscripts entitled:-

"Mitigating the Effects of Septic Tank Effluents from Households on Groundwater Quality: A Case of Meanwood – Kwamwena, Lusaka."

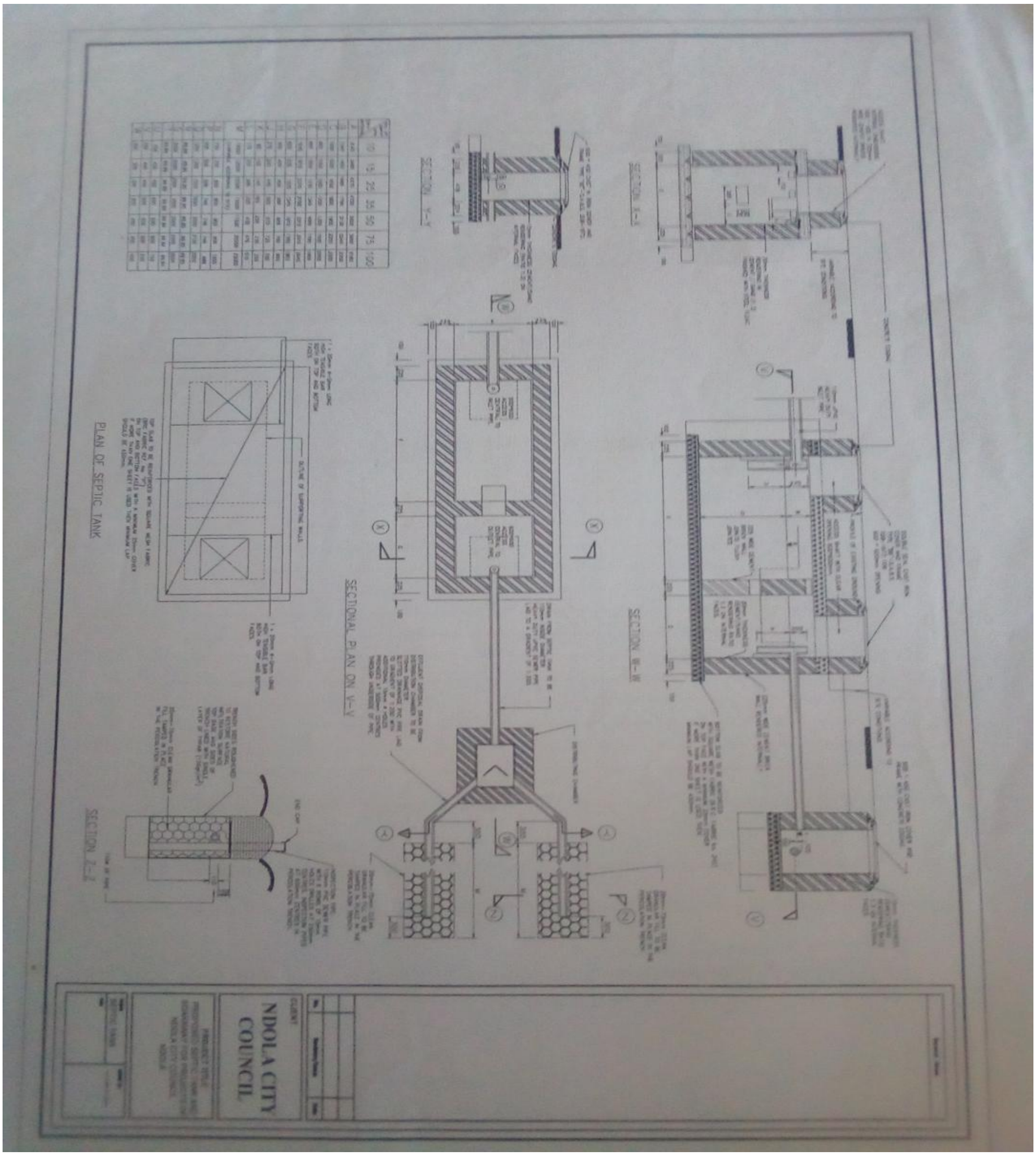
As per requirement, the article will be reviewed and the outcome communicated to you as soon as possible. I wish to thank you most sincerely for your interest in publishing with the Journal of Natural and Applied Sciences.

Yours sincerely,

Dr. Alice M. Mweetwa
ASSISTANT DIRECTOR (RESEARCH)
DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

cc: Director, Directorate of Research and Graduate Studies
Chief Editor, Journal of Natural and Applied Sciences
Assistant Registrar, Directorate of Research and Graduate Studies

APPENDIX F: NDOLA CITY COUNCIL SEPTIC TANK DESIGN STANDARD



APPENDIX G: QUESTIONNAIRE

MITIGATING THE EFFECT OF SEPTIC TANK EFLUENTS FROM HOUSEHOLDS ON GROUNDWATER QUALITY: A CASE OF MEANWOOD-KWAMWENA, LUSAKA

Date: ……………………

ASSESMENT BASED ON THE USE OF SEPTIC TANKS AND BOREHOLES IN THE HOUSEHOLD

(Tick appropriate answer)

1. Do you have a septic tank and borehole?

a) Yes

b) No

2. what is the number of occupants in the household

a) 1-3

b) 4-6

c) 7-9

d) >10

3. Are you aware of design standards for septic tanks?

a) Yes

b) No

Explain your answer.

4 Who provided the septic tank design for the household?

a) the council

b) Others i.e. architect, bricklayers

c) Not sure

Explain your answer.

5. When was the last time the septic tank was pumped out?

a) Never pumped out

b) 2-3 years ago

c) More than 3 years ago

d) Not sure

Brief explanation

6. Are you aware of the required minimum distance between septic tank and borehole

a) Yes

b) No

Explain your answer

7. Do you know that an improperly designed septic tank can contaminate groundwater?

a) Yes

b) No

Brief explanation

8. How often do you taste the borehole water for contamination?

a) Every 6 months

b) One year

c) More than two years

d) Never

Explain your answer

APPENDIX H: SAMPLING SITES, LOCATION AND DESCRIPTION OF AREA

S/N	Height (m)	Coordinates	Area Description
1	1205	S 15^0 35' 35.0" E 028^0 21' 07.0"	Junction between Mtumbi road and Kwamwena Police Post
2	1205	S 15^0 20' 34.1" E 028^0 21' 02.1"	Near Kwamwena Police Post
3	1202	S 15^0 20' 32.1" E 028^0 20' 52.3"	Near Zesco substation
4	1210	S 15^0 20' 30.8" E 028^0 20' 44.5"	Near LWSC boreholes
5	1202	S 15^0 20' 23.6" E 028^0 20' 42.1"	Near Every Thing Meat shop
6	1202	S 15^0 20' 18.4" E 028^0 20' 51.5"	Near boundary between Phase one and two
7	1198	S 15^0 20' 16.4" E 028^0 21' 02.8"	Near LK Hardware Suppliers Shop
8	1199	S 15^0 20' 26.6" E 028^0 21' 05.0"	Near Dangote Shop along Mtumbi Road
9	1202	S 15^0 20' 39.2" E 028^0 21' 09.6"	Near Junction of Galunia Plots and Phase one
10	1207	S 15^0 20' 51.1" E 028^0 21' 11.6"	Near Zamra Christian school
11	1208	S 15^0 21' 01.3" E 028^0 21' 05.6"	Near Mean Park School
12	1213	S 15^0 20' 58.3" E 028^0 20' 56.1"	Near B1 Road entrance
13	1231	S 15^0 20' 52.1" E 028^0 20' 38.9"	Near Mwampy Enterprises Mini Mart Shop

APPENDIX I: ASSESSMENT OF CHARACTERISTICS OF SEPTIC TANKS ON HOUSEHOLDS.

S/N	Variable	Frequency (N=13)	Percentage
1	Septic tank and Borehole on site		
	Yes	13	100
	No	0	0
	Total	**13**	**100%**
2	Number of occupants in the household		
	1-3	1	7.7
	4-6	4	30.8
	7-9	7	53.8
	> 10	1	7.7
	Total	**13**	**100%**
3	Awareness of Design standards		
	Yes	5	38.5
	No	8	61.5
	Total	**13**	**100%**
4	Who provided the Septic Design		
	Council	1	7.7
	Other	9	69.2
	Not Sure	3	23.1
	Total	**13**	**100%**
5	When was the Septic tank pumped out		
	Never pumped out	10	76.9
	2-3 years ago	0	0
	More than 3 years ago	0	0
	Not sure	3	23.1
	Total	**13**	**100%**
6	Awareness of minimum distance between Septic tank and Borehole		
	Yes	4	30.8
	No	9	69.2
	Total	**13**	**100%**
7	Awareness of groundwater contamination from poorly constructed septic tank		
	Yes	5	38.5
	No	8	61.5
	Total	**13**	**100%**
8	Frequency of testing borehole water for contamination		
	Every 6 months	3	23.1
	Every 12 months	1	7.7
	More than two years	3	23.1
	Never	6	46.1
	Total	**13**	**100%**

APPENDIX J: INTERVIEW GUIDE FOR STAKEHOLDERS

Position of respondent:		Date:
Name of organisation:		Email / Telephone:
S/N	QUESTION	RESPONSE
1	How is OWTS developed and provided in Peri urban settlements	Yes or No Explain your answer………………….
2	Do the mandate service providers (Las and utility companies) posses enough capacity (Financial and technical) to develop Peri urban sanitation.	Yes or No Explain your answer………………….
3	In the absence of Mandate institutions, who is responsible for funding and supporting development of Peri urban sanitation?	Yes or No Explain your answer………………….
4	Do you know any national policies and legal provisions available for the provision and delivery of sanitation in peri urban settlements?	Yes or No Explain your answer………………….
5	If Yes, are these policies and legal provisions clear on how to regulate and deliver sanitation services in peri urban settlements?	Yes or No Explain your answer………………….
6	What provisions and regulations are applicable to planning and delivery of sanitation services in Peri urban settlements?	Yes or No Explain your answer………………….
7	Do regulatory authorities and service providers enforce regulations that exist and which require households to have access to basic sanitation	Yes or No Explain your answer………………….
8	Is there a consultative process involving stakeholders in developing OWTS for Peri urban settlements?	Yes or No Explain your answer………………….
9	Do you think Environmental Impact Assessment (EIA) should consider aspects of boreholes and septic tanks systems?	Yes or No Explain your answer………………….
10	Are there national guidelines or standards for development of OWTS for Peri urban settlements?	Yes or No Give Examples……………
11	If Yes, do you give these standards or designs to developers and inspect the construction of the same?	Yes or No Explain your answer………………….
12	Do you have a record of borehole and septic tanks that have been sank in meanwood kwamwena?	Yes or No Explain your answer………………….
13	Do you think onsite effluent disposal systems can have an impact on the groundwater quality if not well located?	Yes or No Explain your answer………………….
14	Are the staff in the mandate institutions well qualified to undertake the inspections of OWTS?	Yes or No Explain your answer………………….