AN ASSESSMENT OF THE CONTRIBUTION OF FAECAL DISPOSAL PRACTICES ON THE BACTERIOLOGICAL QUALITY OF DRINKING WATER SOURCES IN ISIOLO COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment for the Requirements of the Award of Master of Science Degree in Environmental and Occupational Health of Egerton University

EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and to the best of my knowledge has not been presented for the award of a degree in any other institution.

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Recommendation

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DEDICATION

I dedicate this work to my late mum, Mary Achieng Okullo. Her last words of encouragement kept ringing in my mind and propelled me to this end.

To my dad, John Okullo your steadfast encouragement can never be forgotten. Thank you very much for the support.

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ABSTRACT

The basic needs of people such as safe drinking water, improved hygiene and sanitation must be fulfilled for a dignified life of human beings. However, this has not been the case in Isiolo County where there is rampant practice of open defecation and reliance on unprotected water sources for drinking purposes, with little or no regard to adequate drinking water treatment handling and storage. This study sought to establish the contribution of faecal disposal practices among residents on bacteriological quality of drinking water sources in the County. In a cross-sectional survey of 150 households, data on faecal disposal and water handling practices was obtained through questionnaires, observation and key informant interviews. In addition, water samples from both source and household stored water were subjected to bacteriological analysis using the Membrane Filtration Technique (MFT). The data was then analysed using descriptive and inferential statistics at $\alpha = 0.05$ level of significance. According to the findings, the water sources sampled recorded high levels of contamination with bacterial pathogens. Results indicated mean counts of 7.9, 2.1, 5.3, and 6.4 (x 10^3CFU/100ml) from water source and 5.8, 1.6, 3.6 and 3.8 (x 10^3 CFU/100ml) from household stored water samples for *Faecal streptococci*, *Escherichia coli*, *Salmonella typhi* and Total coliform respectively with contamination levels falling below the World Health Organization (WHO) recommended standards. Sanitary risk analysis around these water sources revealed low levels of hygiene and poor source protection in 78% of the water sources, making them prone to faecal contamination. At the household level, 43% of the households surveyed did not have access to latrine facility, promoting un-healthy behaviour such as open defecation, burying and paper bag disposal of faecal matter among households. From the study findings, it was concluded that poor faecal disposal practices and low levels of hygiene among households could be linked to poor bacteriological quality of drinking water. There is need to increase households access and use of latrines. In addition, it is necessary to instil safe drinking water treatment and handling practices especially at point of use. This will help minimise the negative health impacts associated with consumption of faecal contaminated water at households.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
CHW	Community Health Worker
CLTS	Community Led Total Sanitation
CFUs	Colony forming units
CPHO	County Public Health Officer
EC	*Escherichia coli*
FIB	Faecal Indicator Bacteria
GPS	Global Positioning System
GoK	Government of Kenya
ICIDP	Isiolo County Integrated Development Plan
KNBS	Kenya National Bureau of Statistics
ML	Millilitre
MFT	Membrane Filtration Technique
NACOSTI	National Council for Science, Technology and Innovation
OD	Open Defecation
ODF	Open Defecation Free
ODNF	Open Defecation Not Free
ROC	Risk of Contamination
TC	Total Coliform
SDG	Sustainable Development Goals
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation
WRA	Water Resources Authority
VIP	Ventilated Improved Pit

CHAPTER ONE

INTRODUCTION

1.1 Background information

Open defecation is the practice of defecating outside, in and around the local community as a result of lack of access to toilets, latrines or any form of improved sanitation (Bartram *et al*., 2012). According to the Sanitation Update report by World Health Organization (WHO), close to 1.3 billion people are practicing open defecation and 2.6 billion people lack access to improved sanitation, almost all in developing countries and predominantly in rural environments (WHO, 2015). India for instance, has the largest number of open defecators in the world, estimated to be over 600 million of them (Coffey *et al*., 2014). The United Nations approximates that 14% of the population in Democratic Republic of Congo are open defecators. Nearly 540 million people, more than 60% of Africa's population, currently do not have access to safe sanitation, defined as an improved latrine or septic tank. According to MacDonald and Calow (2009), more than a third of Africans practice open defecation, mostly in the rural areas.

The practice of open defecation is common in Kenya, both in rural and urban areas. For instance, Nairobi, the capital city of Kenya, is home to over 4 million people of whom 60% live in informal settlements (WHO, 2010). In these informal settlements, there is limited access to improved sanitation facilities and the existing ones are typically in a state of disrepair and not connected to the municipal sewerage system (Montgomery *et al.*, 2009). This creates a scenario where residents defecate in plastic bags, which are then disposed off in an ad hoc manner (WHO, 2010).

Among pastoralist communities, open defecation is a common practice. Onganya *et al*. (2012) attributes this practice to the nomadic lifestyles that hinder the provision of permanent sanitation facilities. Isiolo lies in an ASAL area with latrine coverage as low as 22%, with open defecation prevailing in numerous rural environments of Isiolo County (ICIDP, 2010). In 2011, the Ministry of Health (MOH) under the Open Defecation Free (ODF) Rural Kenya Roadmap rolled out an implementation plan which sought to declare several villages of Isiolo County open defecation free (UNICEF 2013; GoK, 2011). This has however been met by challenges though the program is still on-going. Musa (2015) further explains that open defecation is a major contributing factor to a multiplicity of water and sanitation related diseases, such as diarrhoea, cholera and typhoid. An estimated 80% of all diseases and one-third deaths in developing countries are caused by consumption of contaminated water and one-tenth, on average of each person's productive time is sacrificed to water related diseases (WHO, 2010).

Open defecation deteriorates the quality of drinking water, making the water unfit for drinking purposes (Tambekar and Neware, 2012).

Water acts as a medium for the transfer of a number of infectious pathogens and a wide range of diseases of microbial origin. According to Rajgire, (2013), faecal contamination of water leads to introduction of a number of enteric pathogens such as *E. coli,* which causes a number of water- borne infections. According to World Health Organization statistics, about 600 million episodes of diarrhoea and 4 million childhood deaths are reported globally per year due to drinking contaminated water and due to lack of proper sanitation. Lack of adequate sanitation also pollutes drinking water, which most significantly due to open defecation and has adverse impacts on human health (WHO, 2010). There is hence need for an assurance of drinking water safety since this will help in the prevention and control of water borne diseases. This study, therefore, was conducted in order to assess the influence of open defecation on the bacteriological quality of drinking water sources within Isiolo County, Kenya.

1.2 Statement of the problem

Sanitation coverage in Isiolo County is low and is characterised with rampant open defecation parctices. In addition, scarcity of potable water remains a key problem among majority of the households. This is because piped water, which is relatively safer, is in most cases provided in Isiolo town and sub-urban environments hence majority of the rural population rely on unprotected water sources that could be prone to faecal contamination. Water scarcity and economic constraints in Isiolo has led to the use of water from these unprotected sources without establishing its quality before use, thus exposing residents to health risks and propably reported high incidence of waterborne diseases within the County. Therefore, there is the need to provide data on faecal disposal practices and on the bacterialogical quality of water sources within the study area. This was achieved through collecting information on the faecal disposal practices and data on the microbiological quality of drinking water sources within the study area. This information will help inform water and sanitation interventions in an effort to safeguard human health amongst communities in Isiolo County.

1.3 Objectives

1.3.1 Broad objective

To assess the contribution of faecal disposal practices on the bacteriological quality of drinking water sources in order to safeguard human health in Isiolo County.

1.3.2 Specific objectives

i) To assess the sanitation characteristics in the Open defecation free (ODF) and Open defecation not free (ODNF) areas in Isiolo County.

ii) To document the various drinking water sources used by the residents of Isiolo and the household water handling practices involved.

iii) To analyse and compare enteric pathogen levels of *E. coli*, *Faecal streptococci*, Total coliform and *Salmonella typhi* in drinking water sources and at point of consumption (selected households) within the study area.

iv) To assess and map out the spatial distribution of open defecation points and latrine coverage in the study area.

1.4 Research questions

i) What are the sanitation characteristics in open defecation free and open defecation not free areas in Isiolo County?

ii) Which are the drinking water sources used by the residents of Isiolo County?

iii) Which are the household water treatment and handling practices used by the residents of Isiolo County?

iv) What are the comparison levels of *E. coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliforms between the various water sources and at point of consumption (selected households) within the study area?

v) What is the spatial distribution of open defecation points in relation to latrine coverage in the study area.

1.5 Justification of the study

Availability of adequate potable water remains a challenge in many parts of the world (Montgomery *et al.*, 2009; Gunther and Fink, 2010). The use of water from un-improved sources has resulted to numerous health risks such as water borne diseases (Galan and Graham, 2013). Isiolo county is characterised by high incidences of open defecation occasioned by low latrine coverage and use. In 2011, an Open Defecation Free Rural Kenya Campaign Road Map was launched aimed at ending open defecation in rural villages of Isiolo County by 2013 (GoK, 2011; UNICEF 2013). Isiolo county, being prone to high cases of waterborne diseases such as numerous cholera outbreaks, was considered suitable for the study in a bid to understand the origin of faecal contamination of drinking water sources within the county, for appropriate intervention measures. The study is in line with Kenya's Vision 2030 under the social pillar, which aims at a just and cohesive society with social equity in a clean and secure environment

(GoK, 2007). The relevant sectors of government like public health and environment will use the study findings in the development of appropriate intervention programs to ensure good health and well-being and ensured access to clean water and sanitation as espoused in the United Nation's Sustainable Development Goals (SDG's), with Goal 3 focussing on universal access health and Goal 6 aimed at ensuring clean water and sanitation by 2030 (United Nations, 2015). The research will also contribute positively to realising the Ministry of Health ODF Rural Kenya Campaign Roadmap, which entails working through partnerships and devolved government structures throughout rural Kenya to reach all the communities and ensure that they are open defecation free (GoK, 2011). The research thus aims to identify and map open defecation hotspots within the study area, information that will be useful to water, sanitation and hygiene actors within the County of Isiolo.

1.6 Scope of the study

The study was conducted in Isiolo Sub-County, in two wards of namely; Ngare Mara and Burat wards in both the open defecation free (ODF) and open defecation not free (ODNF) villages and targeted both surface and below ground community drinking water sources. A cross-sectional survey was conducted to assess faecal disposal practices, determine the drinking water sources mostly used by the communities and the water treatment methods at households. Sanitary surveys accompanied by water sample collection were done in the selected drinking water sources for bacteriological analysis. Mapping was also done to indicate the extent of open defecation while relating it to latrine coverage.

1.7 Assumptions of the study

The study focused on sanitation practices and related them to potential contamination of the community drinking water sources. The study therefore assumed that the level of sanitation in terms of disposal of human waste had a strong bearing on the microbiological water quality of the adjacent water sources.

1.8 Limitations

Engaging in discussions regarding open defecation is a taboo among many pastoral communities. Some of the respondents were therefore reluctant to respond freely on issues regarding faecal disposal practices especially in open defecation prone areas. However, observations were made within the study households to gather more information on faecal disposal habits. Communication barrier especially in remote villages was also a challenge with some respondents hence assistance for translation by trained local research assistants.

1.9 Definition of key operational terms

Drinking water- refers to water used, or intended to be available for use by humans for drinking, cooking, food preparation, personal hygiene or similar purposes.

Household – A group of people living together in a house or homestead. It also refers to a group of people habitually eating and sleeping together in the same compound.

Hygiene- Refers to personal and household practices that serve to prevent infection and keep people and environments clean.

Improved drinking water source- is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter.

Improved sanitation facilities-refers to sanitation facilities which hygienically separate human excreta from human contact.

Latrine Coverage- Proportion of households having ownership of an improved latrine facility.

Open defecation-This refers to the practice of defecating outside and in public, in and around the local community as a result of lack of access to toilets, latrines or any form of improved sanitation.

Open defecation free- An area is open defecation free when there is absence of the practice of open defecation in a prescribed community, region or nation.

Open defecation not free- Refers to the presence of open defecation practices in a presecribed community, region or nation.

Potable water- means water that has been treated, cleaned or filtered and meets established drinking water standards or is assumed to be reasonably free of harmful bacteria and contaminants, and is considered safe to drink or use in cooking and bathing.

Sanitation- refers to the systems for provision of facilities and services for safe disposal of human urine and faeces. It also means building and availability of clean latrines as well as safe disposal of sewage.

Sanitary inspection- is an onsite inspection of a water supply to identify actual and potential sources of contamination.

Waterborne diseases- any illness caused by drinking water contaminated by human or animal faeces, which contain pathogenic micro-organisms.

Water handling- Refers to the household practices of water fetching, treating and storage.

CHAPTER TWO
LITERATURE REVIEW

2.1 The concept of open defecation

Bartram *et al.* (2012), defines the concept of open defecation as the practice of defecating outside, in and around the local community as a result of lack of access to toilets, latrines or any form of improved sanitation. Such locations are usually denoted as 'Open defecation prone areas' characterised by rampant open defecation practice and absence of proper sanitation facilities, with little or no measures having been taken to eliminate the practice (Joshi *et al.*, 2013).

Open defecation despite the obvious health hazards it poses to the society is still a common practice especially in many parts of the world. In a study conducted in Rural North India to assess the practice of open defecation among households, it was found that certain households still preferred engaging in open defecation despite having access to latrine facilities (Coffey *et al.*, 2014). In the study, 47% of the respondents explained that they do so because it is pleasurable, comfortable, or convenient. Further, defecating in the open provides them an opportunity to take a morning walk, see their fields, and take in the fresh air hence regard it as part of a wholesome, healthy, virtuous life.

2.2 Trends of open defecation

Open defecation still remains a challenge in most parts of the world with approximately 1.1 billion people practicing open defecation worldwide and this account for about 15 % of world's population (Galan and Graham, 2013). In reality, it is also estimated that 1 out of 7 individuals engage in open defecation globally. A report on "Progress on Drinking Water and Sanitation Update", explains that Southern Asia and sub- Saharan Africa have been shown to have the highest open defecation prevalence (WHO, 2012). The highest cases of open defecation have been reported in India, with the practice being rampant daily on railway tracks, river side and open fields (Doron and Raja, 2015).

In Africa, it is estimated that 25% of population still practice open defecation, 8% urban and 35% rural (WHO, 2012). The impact of open defecation lies on the risk of diarrhoeal diseases and parasitic infections. The challenges of open defecation have been witnessed too in Kenya. According to the Kenya National Bureau of Statistics (KNBS), about 14% (1,196,000 households) of the total Kenyan households lacked sanitation facilities (GoK, 2010). The report further states that close to 21 million Kenyans use unsanitary or shared latrines and a further 5.6 million people practice open defecation. Open defecation practice has been found to deteriorate the quality of drinking water, hence making the water unfit for drinking purposes (Tambekar and Neware, 2012). The practice of open defecation has also been witnessed in arid areas of Kenya like Isiolo where there are pastoral communities, who constantly move in search of water and pasture for their livestock (GoK, 2011). This nomadic populations do not prioritize digging of pit latrines due to their sedentary lifestyle. Hence, they defecate in the bush which eventually leads to contamination of unprotected water sources which they share with their animals (Jagals *et al.*, 2004).

2.3 Factors promoting open defecation practice

According to Moruff (2012), there are many reasons for open defecation; among them are habit, nomadic cultural lifestyle and poor design of public toilets. Galan and Graham (2013), while exploring changes in open defecation prevalence in sub-Saharan Africa, explains that outdoor defecation is a result of everyday practice formed during childhood and that it is very common among people living in rural areas. Available open space and poor understanding of health and hygiene are factors responsible for the formation of open defecation habit (Coffey *et al.*, 2014). Bartlett (2003) however argues that when there are no toilets available or when people are accustomed to the practice, then open defecation becomes a norm. This claim is supported by a study conducted in Krishnagiri District of India, which revealed that only forty per cent of households had toilets, out of which only 18.9% were functional. The reasons for their non-functionality ranged from improper installation and choked toilets to pit leakages. This prompted individuals to look for alternative relief places such as bushes and along river courses (Balasubramanian, 2013).

In some areas, it was noted that there exists a perception barrier to toilet construction. According to Geetha and Kumar (2014), in a research conducted to establish open defecation awareness and practices of Rural Districts of Tamil Nadu, India it was found out that people were against toilet usage because they believed that it was unhygienic to have toilets near their houses. They believed that open defecation was cleaner, more so during shortage of water. They also asserted that using toilets was culturally incorrect, hence even for functional toilets were used as store rooms and filled with cow dung flakes or other materials. The lack of capital to build toilets also compounds to the problem of open defecation. This is according to a study on the challenges to achieving sustainable sanitation in informal settlements of Kigali, Rwanda, which cited cost as a barrier to achieving sustainable sanitation. Many of the residents preferred to rather engage in open defecation or better go for low cost sanitation options (Tsinda *et al.*, 2013).

2.4 Efforts towards open defecation eradication

2.4.1 Open defecation free (ODF) verification process

Open defecation free (ODF) verification process is a facilitation process used to achieve ODF status and has been very effective in promoting the adoption of other critical hygiene behaviour (Musyoki, 2010). The verification process generally seeks to validate the submission of communities and builds on the key indicators of ODF areas. These indicators include; that there is no evidence of open defecation, that households have access to latrines, that hand-washing with soap facilities are present and that children's faeces are disposed of safely (Chambers, 2009).

Communities are usually expected to apply for ODF verification to local or district-level officials. Once verified, a certificate is usually given to the community leaders to establish their status as ODF. Thereafter, a date is commonly set after this to celebrate ODF status and the event can be done collectively (between several newly ODF villages) at a district level, or locally (Bwire, 2010). According to Chambers (2009), the most critical factors for sustaining behaviour change are post ODF monitoring and follow up visits to support communities in developing sustainable facilities, access to needed technical support and to develop plans for the long term upkeep of ODF status. Figure 1 demonstrates a process to declare a village as open defecation free (ODF).

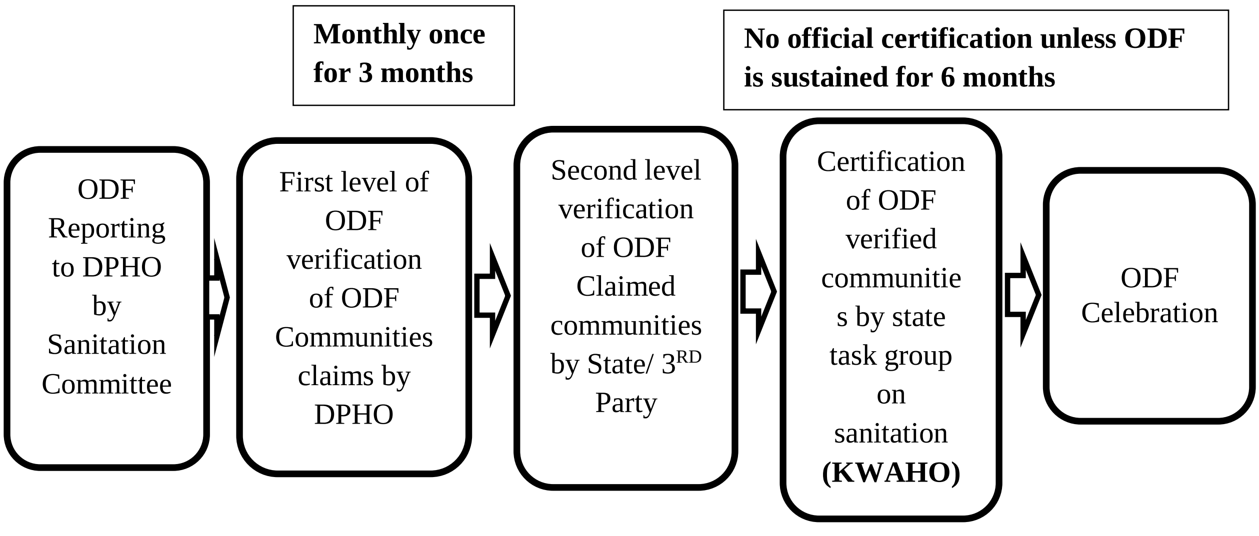


Figure 1: An ODF declaration process (Adapted from WHO/UNICEF, 2010)

In Kenya, the Open defecation free (ODF) program was introduced in 2007 in three districts namely; Kilifi, Homabay and Machakos districts by Plan International Kenya (Bwire, 2010; Musyoki, 2010). The project has then since been rolled out to many areas of Kenya under the ministry of health ODF Rural Kenya Campaign Roadmap set to achieve a target of totally open defecation free communities by the year 2017 (GoK, 2011).

2.4.2 Community Led Total Sanitation

The Community Led Total Sanitation (CLTS) approach was invented by Dr Kamal Kar in Bangladesh in 1999-2000 (Mehta and Movik, 2010). CLTS facilitates the community's analysis of their sanitation profile, their practices of defecation and the consequences, leading to collective action to become ODF. The approach has widely been seen as a useful tool in the eradication of open defecation in many parts of the world (Chambers, 2009). To demonstrate the effectiveness of this approach, an explanation is given by a study that was conducted in the Orissa State, on the impact of Indian total sanitation campaign on latrine coverage and use (Barnard *et al.,* 2013). The study revealed that there was a marked increase in latrine use and coverage where the programme had been rolled. This is after the study results indicated a mean latrine coverage among the villages at 72%, compared to <10% in comparable villages in the same district where the Total Sanitation Campaign had not yet been implemented.

CLTS has also been shown to be an effective approach for eliminating the practice of open defecation in Malawi (Msyamboza *et al.,* 2012). Since its introduction over 2000 villages have been triggered in 12 districts, over 800 of which have been declared "Open Defecation Free" (ODF), a 37% triggering vs. ODF rate. Given its potential to promote significant health benefits, the government of Malawi decided to scale-up the approach in all 28 districts in 2014. Another study was conducted to explore community members' and stakeholders' sanitation, knowledge, perceptions, and behaviours during early CLTS implementation in six districts in Zambia (Lawrence *et al.*, 2016). According to the results of the study, triggering activities elicited strong emotions, including shame, disgust, and peer pressure, which persuaded individuals and families to build and use latrines and hand-washing stations.

In 2007, the Ministry of Health (MOH) launched the Community Led Total Sanitation (CLTS) approach in many villages of Kenya in areas like Kilifi, Nyando, Kajiado, Siaya, Turkana, Busia, Bondo, Kisumu West, and Rachuonyo districts among others to eradicate open defecation and achieve open defecation free (ODF) villages (WHO/UNICEF, 2010; Bwire, 2010). To date, ODF status has been achieved in more than 1,369 villages (World Health Organization, 2012). In addition, 850 villages have been verified by the DPHOs and are awaiting Third Party Certification in Kenya (Mehta and Movik, 2010). Through the CLTS Programme, the Government of Kenya through the Ministry of Health (MOH) intends to make the whole country ODF by the end of 2017 using CLTS as a tool (GoK, 2011).

2.4.3 Community Led Action for Sanitary Surveillance

The Community Led Action for Sanitary Surveillance (CLASS), an almost similar to CLTS is a community based approach aimed at ensuring reliability of drinking water quality both at the production and the consumption levels (Mehta and Movik, 2010). CLASS however is founded on the idea that community analysis of all drinking water sources and awareness of recommended water treatment, handling, usage and management practices can effectively trigger community-wide action in order to prevent bacteriological contamination. The CLASS approach was implemented in 35 villages of Uttarhakhand, India and it demonstrated that it was an effective tool in water quality surveillance and monitoring (Murugesan *et al.,* 2008). As an outcome of the initiative, some of the ODF communities started with low cost sanitation toilets and later moved to more durable permanent ones. Also, some communities fined defaulters, in order to stop open defecation in villages and in schools. Other actions taken included, repairing broken hand-pump platforms, covering water pots, boiling drinking water or treating by chlorine tablets in households, cleaning and protecting water sources, banning of washing clothes near community water sources and banning open defecation.

2.5 Classification of drinking water sources

The Joint Monitoring Programme for Water Supply and Sanitation gives classification of improved and un-improved water sources as indicated in Table 1.

Table 1: JMP Classification of drinking-water source types

Source class	Type of source
Unimproved drinking-water source	Unprotected dug well, unprotected spring, cart with small tank or drum, surface water (e.g., river, dam, lake, pond, stream, canal or irrigation channel) and bottled water
Improved drinking-water source (piped to dwelling, plot or yard)	Piped water connection located inside the user's dwelling, plot or yard
Improved drinking-water source (other sources)	Public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection

Source: WHO/UNICEF, 2010

The World Health Organisation (WHO) and UNICEF estimate that 5.8 billion people globally were using improved sources in 2010, while 783 million used unimproved water sources (WHO/UNICEF, 2010). This scenerio points to the challenge of accessing potable water among worlds majority population.

2.6 Bacterial indicators of faecal pollution

Water quality is assessed by measuring faecal indicator bacteria (FIB) in water. Faecal indicator bacteria (FIB) are those which naturally occur in the gut of humans and other warm-blooded animals, and are used to indicate the occurrence of faecal contamination (Hennani *et al.,* 2012).

2.6.1 *Escherichia coli*

Escherichia coli (*E. coli*) is a gram negative bacterium, facultative anaerobic, rod shaped bacterium of the genus Escherichia that is commonly found in the lower intestine of warm blooded organisms (Croxen *et al.,* 2013). *E. coli* is most frequently used measure of water quality as it serves as an indicator of contamination rather than an index or risk or the degree of contamination (World Health Organization, 2010). *E. coli* counts was used to assess tube-well water quality and predictors of contamination in three flood-prone areas in Bangladesh, with the aim of determining the association between tube-well contamination with *E. coli* and a poor sanitary risk score (Luby *et al.,* 2008). The study concluded that tube-wells in flood-prone regions of Bangladesh were commonly contaminated with low levels of faecal organisms, contamination that could not be predicted by examining the tube-well's external characteristics. A study conducted to assess household water quality associated *E. coli* to poor sanitation among households (Hamoudi *et al.*, 2012).

2.6.2 *Salmonella typhi*

Bacteria of the genus Salmonella are gram- negative, facultatively anaerobic, non-spore forming, usually motile rods belonging to the family Enterobacteriaceae and primarily associated with animals. It inhabits the lymphatic tissues of the small intestine, liver, spleen and blood stream of infected humans (Figueras and Borrego, 2010). The genus currently contains only two species, *Salmonella enterica* and *Salmonella bongori*. Most of the salmonella isolates from cases of human infection belong to *Salmonella enterica* subspecies *enteric* (Krenkel, 2012). A study by Fuller *et al.* (2014) demonstrated increased diarrhoeal prevalence in young children to the presence of *Salmonella typhi* pathogens in environments with poor sanitation.

2.6.3 *Faecal Streptococci*

The faecal streptococci generally are members of the genera Streptococcus and Enterococcus. These bacteria are spherical, gram positive and grow in chains often found in high concentrations in the gastrointestinal tract. They are more persistent than *E. coli* (Trevett *et al.,* 2005). They have been found to be a key contributor to microbiological contamination of water sources. A study of water quality variation in shallow protected springs in Kampala was undertaken over a 12-month period to assess the causes of microbiological contamination. It was found out that there was marked concentration of faecal streptococci after spring recharge from a rainfall event (Howard *et al.,* 2013).

2.6.4 Total coliforms

Total coliforms are a group of related bacteria that are, with few exceptions, not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. Environmental Protection Agency (EPA) considers total coliforms a useful indicator of other pathogens for drinking water. Total coliforms are used to determine the adequacy of water treatment and the integrity of the distribution system (WHO/UNICEF, 2011). A study conducted in Open Defecation Free and Open Defecation Not Free villages in Amravati district, India to assess the effects of open defecation as a source of faecal pollution in 211 drinking water samples, indicated high number of total coliform pollution (Tambekar and Neware, 2012). The results indicated that drinking water samples from open defecation free villages had 17% faecal contamination whereas ODNF villages had 48%. Fifteen percent (n=7) of these drinking water samples, were found to be contaminated by thermo-tolerant coliform.

2.7 Open defecation and water borne diseases infection

Infectious diseases caused by pathogenic bacteria, viruses and parasites are the most common and widespread health risks associated with drinking water faecal contaminated water. Such diseases include cholera, typhoid, dysentery, hepatitis, giardiasis, guinea worm and schistosomiasis (Hennani *et al.,* 2012). Diarrheal disease, caused by a number of different enteropathogens, remains a leading cause of global child mortality and morbidity, especially in children under five and among the immunocompromised (Fuller *et al.,* 2014). Globally, an estimated 1.7 million people die annually, largely through waterborne diseases caused by poor water quality and lack of basic sanitation and hygiene (WHO, 2012). A study by Clasen *et al.* (2014), to estimate the burden of diarrhoeal diseases from exposure to inadequate water, sanitation and hand hygiene in low- and middle-income settings in 145 countries, found out that 502,000 diarrhoea deaths were estimated to be caused by inadequate drinking water and 280,000 deaths by inadequate sanitation yearly.

According to WHO/UNICEF (2011), there is vast evidence which substantiate the fact that open defecation can result in increased infant deaths, under-nutrition, stunting and Faecally

Transmitted Diseases (FTDs). These FTDs can effectively cripple the growth of young bodies and minds, among other harms. In a study another study conducted in India, it was observed that 600,000 under-five children died in 2010 due to diarrhoea, pneumonia and other diseases directly linked to a combination of contaminated water supply, unsafe sanitation conditions, and inadequate hygiene practices. Out of these deaths diarrhoea accounted for 212,000 deaths (Montgomery *et al.,* 2009). The study also found out that poor sanitation, hygiene, and open defecation is responsible for 50% of the cases of maternal and childhood under-nutrition. In particular, children who are exposed to more faecal germs had stunted growth.

In Isiolo County, water related deaths are reported yearly. For instance, in the year 2009 to 2010, at least 18 children under 5 years of age died in Isiolo County, Kenya, due to diarrhoeal complications related to poor faecal disposal. Furthermore, high prevalence rates (10.5%) of diarrhoea have been reported in these households, and water scarcity was cited as a major cause (GoK, 2012). Figure 2 demonstrates a cycle of how an individual can become susceptible from taking faecal contaminated water.

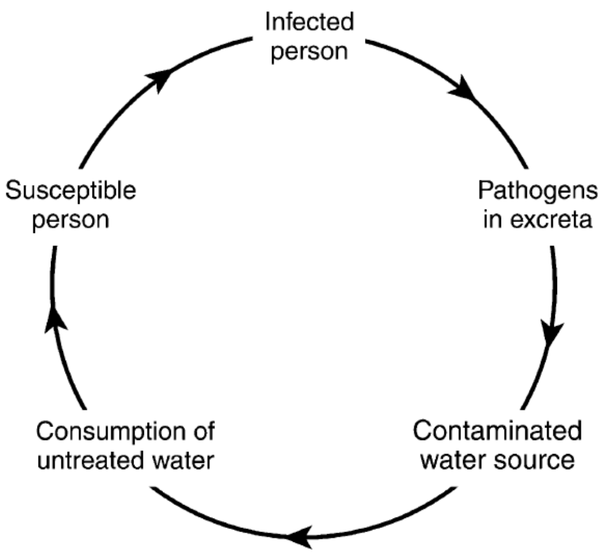


Figure 2: A classical waterborne disease infection cycle (Source: Al-Khateed & Tebbutt, 1992)

Although more emphasis have been laid on the faecal oral disease transimssions, consumption of untreated water remains the common pathway in which humans become infected with waterborne diseases as demonstrated in Figure 2 above.

2.8 Faecal contamination of drinking water sources

Contamination may have impacts directly where water bodies are used for drinking water abstraction or recreation. The risk of microbiological contamination of drinking water during collection and storage in the home has long been recognized (Clasen and Bastable, 2003; Rufener *et al.*, 2010). Where communities take drinking water without proper treatment, they are at risk of suffering from water-borne diseases (Howard *et al.*, 2013).

2.8.1 Interventions to reduce microbial contamination of drinking water

Microbiological contamination is most likely to arise from the entry of faecal matter to waters (Eshcol *et al.*, 2009). Drinking water hence needs to be protected from pollution and biological contamination. Over the years, actors in the sanitation sector have focused on interventions that can reduce contamination of household water and produce a measurable health impact. One intervention developed by the Centres for Disease Control and Prevention (CDC) and the Pan-American Health Organization (PAHO) combines: (i) point-of-use water disinfection using sodium chloride manufactured locally through electrolysis of brine; (ii) a specially-designed water storage vessel with a narrow mouth to prevent ingress of hands and a spigot for drawing water for consumption; and (iii) community hygiene education and training and follow-up in the use of the disinfectant and vessel (CDC, 2001). Trials involving the intervention have demonstrated reductions in the incidence of diarrhoea of 44% in Bolivia (Quick *et al.*, 2002) and 62% in Uzbekistan (Roberts *et al.*, 2001). Even without chlorination, however, an improved collection and storage vessel was associated with a 69% reduction in geometric mean FC count and a 31% reduction in diarrhoea in children under five ($P = 0.06$) (Roberts *et al.*, 2001).

2.8.2 Household drinking water storage and handling practices

Water container handling practices at the household level is likely to determine the safety of the water for the source may potentially be re-contaminated due to poor household handling and storage practices drinking purposes (Rosa and Clasen, 2010). A study conducted in rural households in Kakamega to assess influence of sanitation on drinking water, showed that even drinking water which is safe at the source is subject to frequent and extensive faecal contamination during collection, storage and use in the home (Kioko and Obiri, 2012). Other studies have shown that the bacteriological quality of drinking water significantly declines after collection (Wright and Gundry, 2009; Onabolu *et al.*, 2011), suggesting that safer household water storage and treatment (point-of-use) should be the recommended focus of intervention efforts (Clasen and Bastable, 2003; Clasen, 2015).

The risk of microbiological contamination of drinking water during collection and storage in the home has long been recognized (Clasen and Bastable, 2003). According to Rufener *et al.* (2010), certain practices and vessel characteristics have been associated with the contamination of household water. These include using large-mouth vessels to collect and store water, transferring water from collection vessels to storage vessels and accessing water by dipping hand-held utensils rather than via a tap or by pouring. Household water treatment and safe storage (HWTS), such as boiling, filtering, or chlorinating water at home, have been shown to be effective in improving the microbiological quality of drinking water (Clasen, 2015). This has been demonstrated in a study that was conducted to investigate the knowledge, attitudes and practices of peri-urban households in Kakamega town, Kenya, with regard to the collection, treatment and storage of drinking water (Kioko and Obiri, 2012). The results showed that most respondents were knowledgeable about ideal methods of water collection, treatment and storage. However, they did not practise them appropriately. According to Bartram *et al.* (2012), household water treatment and safe storage interventions can lead to dramatic improvements in drinking water quality and consequently a reduction in diarrhoeal diseases. Similar findings have also been put forward by Levy *et al.* (2008).

2.8.3 Sanitary risk use in determination of water quality

The World Health Organization Guidelines for Drinking-water Quality promote assessment of sanitary risk for all drinking water supplies. Sanitary risk identifies sources of faecal contamination, potential pathways for contamination to reach water and measures to reduce contamination (WHO/UNICEF., 2011). Specifically, surveillance of sanitary risk involves inspection of drinking water systems, the source of the drinking water, activities in the catchment area, transmission infrastructure, treatment plants, storage reservoirs and distribution systems. Sanitary risk has been used in determination of water quality. For instance, a large cohort study in Canada found an association between sewage disposal and endemic infectious intestinal disease (Gunnarsdottir *et al.*, 2012).

2.8.4 World Health Organization microbial standards for drinking water

The World Health Organization (WHO) Guidelines, and most national drinking water standards, take the presence of *Escherichia coli* (*E. coli*) or thermotolerant coliforms as an indication of recent faecal pollution from human or warm-blooded animals (WHO 1993). Thus, the WHO guideline value of zero *E. coli* or thermotolerant coliform bacteria in any 100 ml sample of drinking water was established because even low levels of faecal contamination may potentially contain pathogens. Given these clear and unambiguous guidelines, it is reasonable to conclude that drinking water exhibiting faecal contamination at any point in the distribution to consumption sequence should be cause for concern. However, it has been suggested that where drinking water becomes polluted during its collection and storage in the home it does not represent a serious risk of faecal-oral disease (Onabolu, 2011).

2.9 Relevant policy and institutional frameworks on water and sanitation

There are policy and institutional frameworks that support water and sanitation provision. According to the United Nation's Sustainable Development Goals (SDGs), Goal 3, (Target 3.9) specifically aims at substantially reducing the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination by 2030 while Goal 6, (Target 6.1) aims to achieve universal and equitable access to safe and affordable drinking water for all. In addition, Target 6.2 aims by 2030, to achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations (United Nations, 2015).

Nationally, frameworks such as the Vision 2030 social pillar address water and sanitation (GoK, 2007). Its goal is to ensure increased access to safe water and sanitation in both rural and urban areas beyond present levels. In addition, the National Water Policy published in 2012 by the Ministry of Water Resources seeks to address issues such as the scarcity of water, inequities in its distribution and the lack of a unified perspective in planning, management and use of water resources.

The Kenya Health Policy 2014-2030 was developed in Kenya with the goal of maintaining health standards among communities. It demonstrates the health sector's commitment, under the government's stewardship, to ensuring that the country attains the highest possible standards of health, in a manner responsive to the needs of the population. It is thus responsive to the water and sanitation demands of Kenya's population.

The Water Act, 2016 is an Act of parliament meant to provide for the management, conservation, use and control of water resources in Kenya. Under the Act, the Water Resources Authority (WRA), a state corporation charged with being the lead agency in water resources management in Kenya. WRA is tasked with the responsibility of controlling pollution and improving water quality in the country's water bodies. This is done by intergrating land use activities into WRA water quality control programmes.

The Public Health Act (Revised 2012), provides the impetus for a healthy environment and outlines regulations on waste management, pollution control and Human health. By providing guidelines of water quality, size of rooms, basic hygiene and the optimal sanitation standards.

2.10 Conceptual framework

Contamination of water sources is the greatest threat to water quality, the most serious form being faecal contamination. This contamination is a complex process that cannot be predicted to a high degree of accuracy since several factors may lead to water contamination. However, a conceptual framework helps us to understand which of these factors is important for contamination.

The 'pathogen load' in source or household stored drinking water refers to the concentration and category of pathogens present in the water. The overall water quality, expressed as the pathogen load is usually determined by a number of other factors. Factors in the environment such as those resulting from poor faecal disposal practices usually lead to contamination of water. This is especially dependent on an individual's or households excreta disposal practices. 'Handling' refers to household water management, and specifically to the way in which water is collected, transported, stored and used. Inevitably, the practices surrounding handling will vary between households and communities. Water handling practices determine the extent to which water becomes contaminated between collection and use. 'Hygiene' in this context refers exclusively to hand washing. There is strong evidence to suggest that hand–water contact is a principal cause of the re-contamination of drinking water. It is arguable that hand–water contact is unavoidable in situations where water must be collected, transported and stored. Consequently, if hands are unclean there is a high risk that drinking water will become contaminated as a result of contact made during normal household water management. Thus, improving hygiene/hand washing behaviour leads to reduced water contamination in the household.

Intervening factors related to water contamination were also considered. 'Socio-economic' factors include the level of education and, more specifically, knowledge of good hygiene practice. To some extent making use of such knowledge is dependent on household income. In situations of extreme poverty the household's ability to improve or maintain the sanitary environment of the home will be limited. The 'cultural' factor focuses on the cultural values and norms held by different societies, of which there may be several distinct groups in a country. Different cultural settings have diverent views especially with regard to faecal disposal and this may determine the extent of introduction of pathogens into the environment. The degree of social interaction within families, and between neighbours and strangers is also an important factor in the epidemiology of infection. Figure 3 demonstrates the conceptual framework including the variables that was adopted for the study.

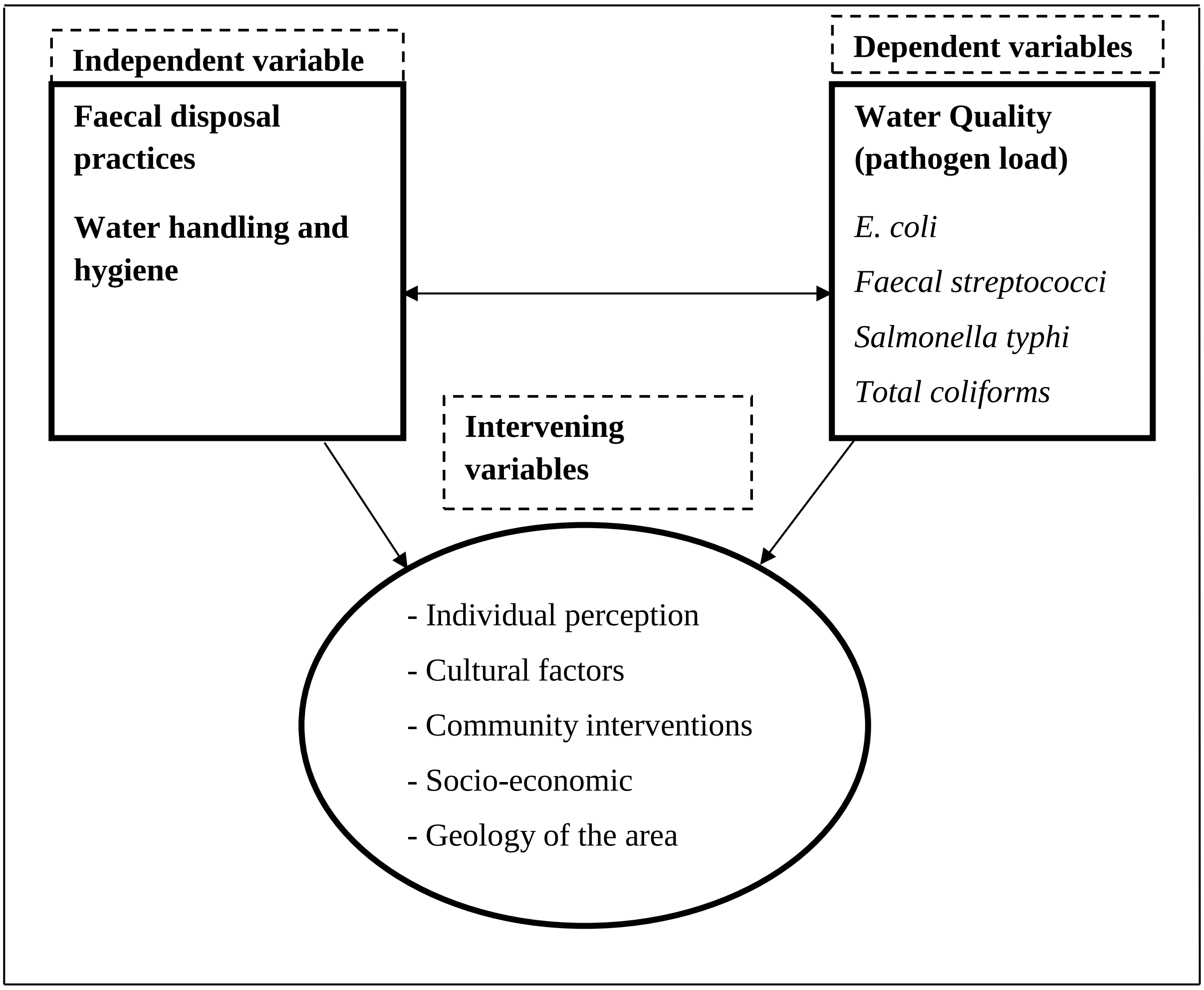


Figure 3: Conceptual framework showing variables in the study

CHAPTER THREE
METHODOLOGY

3.1 Study Area

Isiolo County is situated in the former Eastern province, Kenya, lying 285 kilometres north of Nairobi. It covers an expansive area of 25336.1 Square kilometres. Isiolo town, the county's headquarter lies about the coordinates of 0° 21' 0" North and 37° 35' 0" East. Isiolo County is subdivided into 3 sub-counties namely Isiolo, Garbatula and Merti. Ngare Mara and Burat wards lie in Isiolo sub-county (ICIDP, 2010). The county is classified into three ecological zones namely Semi-Arid, Arid and the very Arid. Rainfall received here is usually scarce and unreliable with annual rainfall ranges between 150 mm to 350mm annually and supports grassland and few shrubs (ICIDP, 2010).

According to the 2009 census report, the county has a total population of 143, 294 with a population density of approximately 6 people Per Square Kilometre (KNBS, 2010). Isiolo County has a cosmopolitan population, which consists of the Turkana, Samburu, Rendille, Borana and Meru tribes. A greater population of Isiolo county lives within Isiolo Central district, while most of the other areas are characterised by nomadic communities. Over 80 % of the land in Isiolo cannot support crop farming and hence is used as grazing land by the pastoralists. Close to 71% of the population live below the poverty line. There is reliance on improved and un-improved water sources in the county which include rivers such as Ewaso Nyiro, Isiolo River and Bisanadi. Additional water sources include boreholes, water pans, sand dams and shallow wells distributed across the County (Figure 4). Despite the presence of these sources, water and sanitation provision still remains a challenge in most parts of Isiolo County, with toilet coverage as low as 22% (ICIDP, 2010). Piped water is only available to residents living in Isiolo town and the immediate surroundings and serves population of about 60,000. Most residents especially in the rural settings therefore rely on unprotected water sources.

The general geology of the Isiolo county has a combination of metamorphic rocks. Other dominants rocks in town and its environs are superficial deposits and tertiary rocks (mainly olivine basalts and merti beds). Within the study area, the dominant soil is sandy, but there patches of black cotton soil and red soils. The alluvium is composed sand and silk of recent deposition. Weak soils found in some of the locations have led to collapse of latines thus posing a challenge to sanitation. Figure 4 shows map of Isiolo County, indicating the study areas of Burat and Ngare Mara wards.

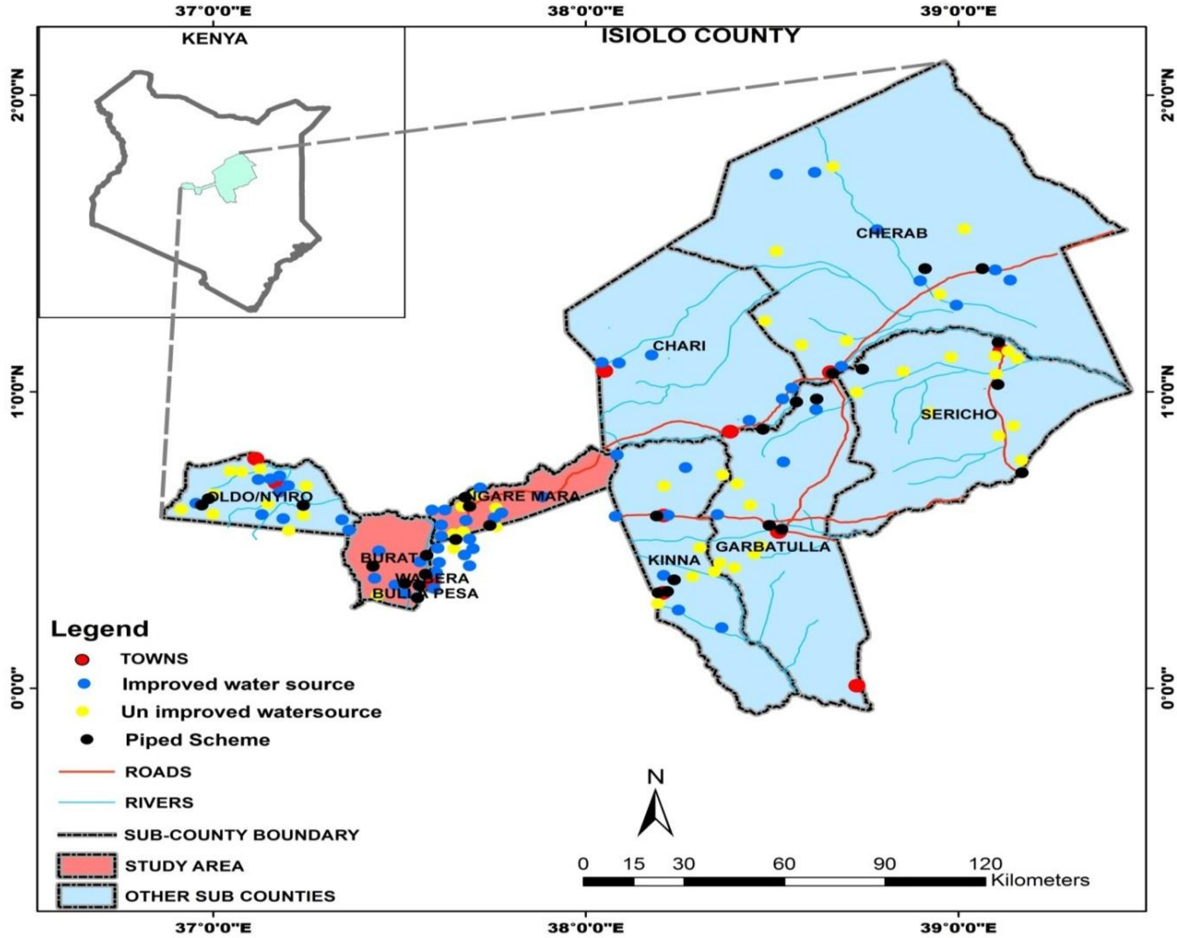
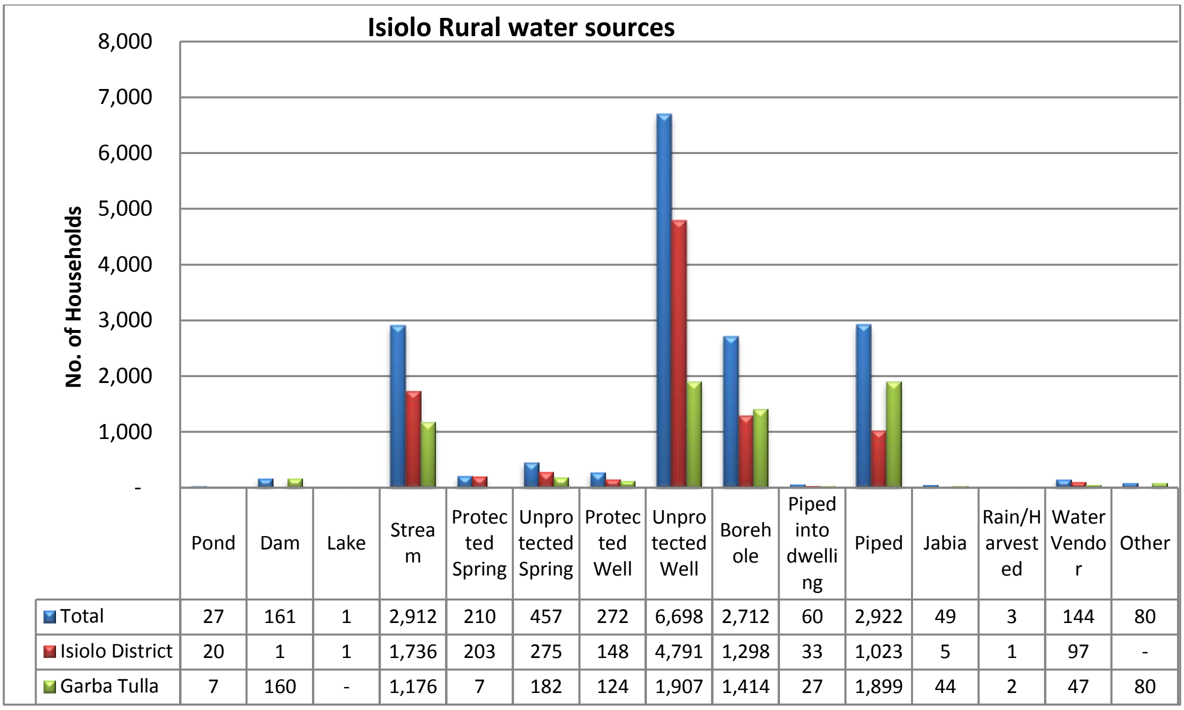


Figure 4: Map of study area; Source: Modified from Isiolo CIDP 2013-2017.

A water and sanitation survey report by the Ministry of Health of Isiolo County revealed that the main sources of water in rural parts Isiolo County are unprotected dug wells, streams, boreholes and piped schemes (GoK, 2012). The report further states that 62% of rural households in Isiolo County rely on unimproved water sources with majority relying on unprotected wells and streams. This has made Isiolo County a focus of water and sanitation interventions. Figure 5 gives an overview of the water sources coverage in Isiolo County.



	Pond	Dam	Lake	Stream	Protected Spring	Unprotected Spring	Protected Well	Unprotected Well	Borehole	Piped into dwelling	Piped	Jabia	Rain/Harvested	Water Vendor	Other
Total	27	161	1	2,912	210	457	272	6,698	2,712	60	2,922	49	3	144	80
Isiolo District	20	1	1	1,736	203	275	148	4,791	1,298	33	1,023	5	1	97	-
Garba Tulla	7	160	-	1,176	7	182	124	1,907	1,414	27	1,899	44	2	47	80

Figure 5: Isiolo County water coverage (Source: GoK, 2012).

3.2 Study design

The research involved a cross-sectional survey design to determine the faecal disposal practices, water sources and water treatment practices within selected households. Data collection methods included questionnaires, observations and key informant interviews. This was followed by the collection of water samples from sources for bacterioloical analysis so as to determine the contamination levels of the water sources.

3.3 Sample size determination

3.3.1 Sampling frame

The study sample frame included community water points upon which bacteriological tests and sanitary surveys were carried out. Two wards namely, Ngare Mara and Burat wards were purposively selected for the study. These wards located within Isiolo Central division, have been reported to have the highest number (78%) of functional drinking water sources (GoK, 2012). In addition, the two wards form centres of focus in Isiolo County on sanitation matters especially relating to the eradication of open defecation practices since they vividly present both improved sanitation and un-improved sanitation scenario (ICIDP, 2010). Households relying on these water sources were randomly sampled to acquire information on faecal disposal behaviour and point of use water treatment, handling and storage practices by the household occupants.

3.3.2 Household sample size determination

The 2009 census data on the number of households in Ngare Mara and Burat wards revealed a total of 952 households within these ward (GoK, 2010). This was used to determine the household sample size, using the following formula recommended by Nassiuma (2000) for minimum sample size determination.

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where,

n: Desired sample size

C: Coefficient of variation

e: Standard Margin of error

N: Total number of accessible households within study area (952 HH),

Taking C = 20% and e = 1.5% in the above formula;

$$n = \frac{952 \times (0.2)^2}{(0.2)^2 + (952-1)(0.015)^2} \mathrm{n} = 149.92$$

$$\mathrm{n} \approx 150 \text{ Households}$$

Households were randomly selected using a two-stage cluster sampling design by which the researcher received lists of current Community Health Workers (CHWs) representing the study communities and where each CHW is responsible for approximately 50 households. From these lists, 6 community clusters were firstly selected at random and then 25 households were selected at random from the CHV household list of each chosen cluster, using a random number generator in both cases. In all, 75 households were selected in Ngare Mara ward and 75 selected in Burat ward.

3.3.3 Description of water sampling sites

The water sampling points included community water sources which were purposively selected into the study. These included water sources with the highest number of users and functionality status within the study wards. A total of 15 sampling sites were identified for study which included 5 hand dug wells, 6 boreholes, 2 river sources and 2 water pans. For identification purposes, the water sampling points were coded 'WS-Water Source' as indicated in the Table 2.

Table 2: Geographical location of sampling sites

Water point name	Coding	GPS Location
St. Paul Kilimani borehole	WS1	00, 21’,33.4’’N/ 370,34’, 06.2’’E
Game Community borehole	WS2	00, 21’,26.1’’N / 370,35’, 08.4’’E
Kampi Juu water project	WS3	00, 23’,36.4’’N / 370,34’, 12.2’’E
Masharkwata well	WS4	00, 21’,38.2’’N / 370,36’, 09.4’’E
Kilimani well project	WS5	00, 22’,32.0’’N / 370,34’, 16.2’’E
Uhuru community borehole	WS6	00, 21’,23.1’’N / 370,35’, 10.8’’E
River Isiolo ‘Site A’	WS7	00, 22’,37.6’’N / 370,33’, 18.2’’E
River Isiolo ‘Site B’	WS8	00, 22’,29.0’’N / 370,35’, 15.6’’E
Sukuma well	WS9	00, 21’,21.4’’N / 370,32’, 12.4’’E
Manyatta Zebra water pan	WS10	00, 22’,28.7’’N / 370,33’, 11.2’’E
Aukot well	WS11	00, 21’,14.2’’N / 370,35’, 13.6’’E
Attan Shallow well	WS12	00, 22’,31.3’’N / 370,33’, 15.7’’E
Kisile water pan	WS13	00, 22’,24.8’’N / 370,34’, 13.5’’E
Kijito Water Project	WS14	00, 23’,37.1’’N / 370,35’, 04.4’’E
Ngare Mara Chiefs borehole	WS15	00, 24’,36.4’’N / 370,35’, 18.3’’E

Legend: WS=Water source

For households, samples were obtained from stored water in vessels and were matched to their source. These samples were obtained in the same manner by which the households access their drinking water. In total, 15 water samples were obtained from the households.

3.4 Data collection

Permission to conduct research was sought from the National Council for Science and Technology (Permit No. NACOSTI/P/17/71277/16237) and Ministry of Health (MOH) department in Isiolo County, who are responsible for the study area to enable the researcher to carry out the sampling exercise successfully. For household surveys, data collection was achieved through use of questionnaires, interview schedules and observation. Data on water quality was achieved through sanitary surveys and by the determination of bacterial concentrations of Total coliforms, *Faecal streptococci*, *Salmonella typhi* and *Escherichia coli* using the Membrane Filtration Technique (APHA, 2005). Global Positioning System (GPS) co-ordinate readings of the sampling points were taken and transferred onto a digitised topographic map of the study area to indicate the spatial bacterial densities of the sampled community water points with respect to faecal disposal trends.

3.5 Cross-sectional survey

The research involved conducting household and environmental surveys covering topics related to household and community water, sanitation, and hygiene characteristics and behaviors. This involved random administration questionnaires (*Appendix 2*) to households randomly sampled within the study area. The researcher also collected observational data on household WASH characteristics involving use of observation schedules (*Appendix 4*) and key informant interviews (*Appendix 5*).

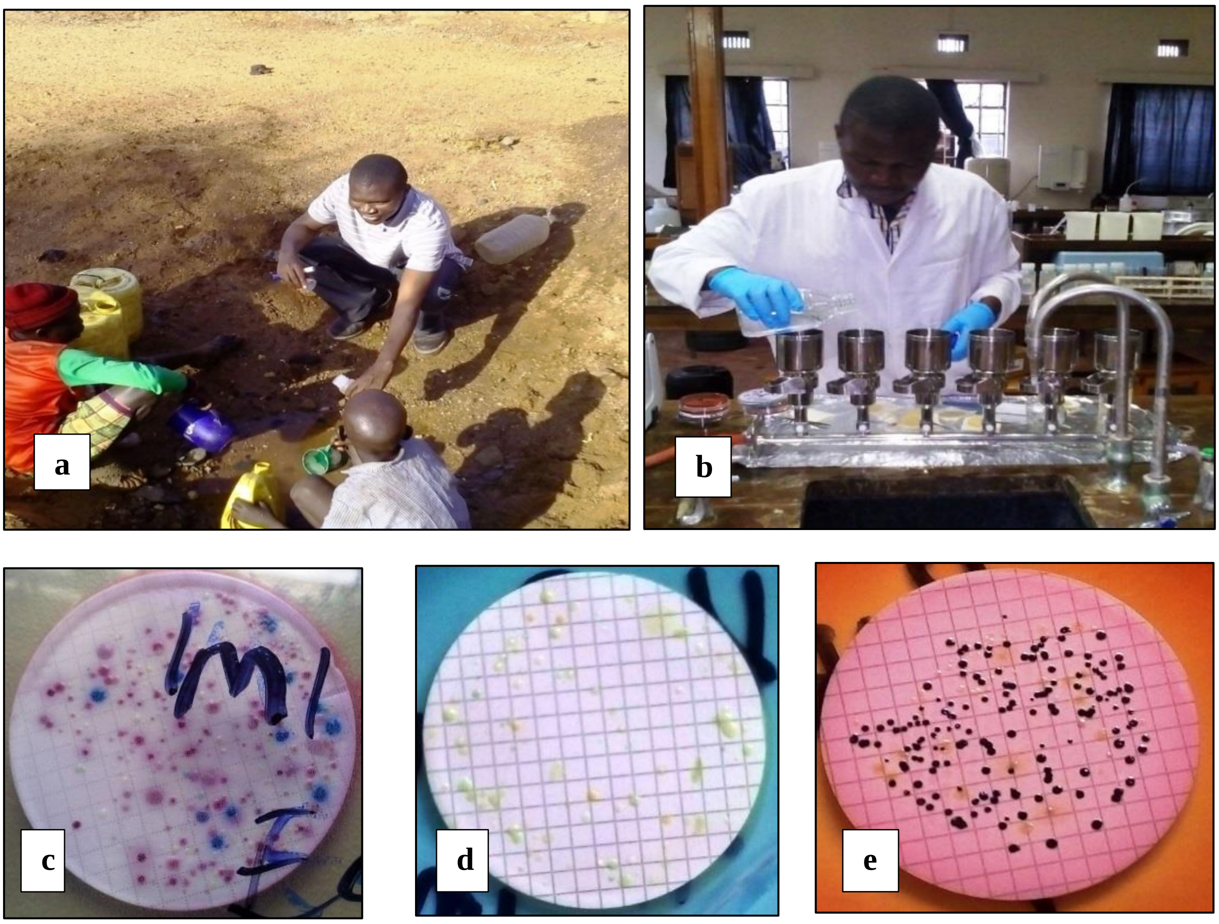
3.6 Sanitary inspection

In order to further assess the potential sources of faecal contamination around water sources, sanitary inspection was conducted. Sanitary inspection, which identifies actual and potential sources of contamination of groundwater abstraction points, was proposed by the World Health Organization as part of the comprehensive and complementary risk-based assessment of drinking water quality (WHO 2007; Luby *et al.*, 2008). This proposal supports the operation and maintenance of water points by providing clear guidance for remedial action to protect and improve the water supply (Luby *et al.*, 2008). The World Health Organization established a format for sanitary inspection forms consisting of a set of questions which have "yes" or "no" answers. The questions are structured such that "yes" answers indicate that there is a reasonable risk of contamination and "no" answers indicate that the particular risk appears to be negligible (*Appendix 3)*. Each "yes" answer scores one point and each "no" answer scores zero points. At the end of the inspection, the points are totalled, yielding a sanitary inspection risk score (in this study, referred to as a risk-of-contamination, or ROC score). A higher ROC score represents a greater risk that drinking water is contaminated by faecal pollution from the area immediately surrounding the water point (WHO, 1997; Luby *et al.,* 2008; Parker *et al.,* 2010).

3.7 Water samples analysis for bacteriological parameters

Analysis of water samples for various types of microbiological indicators of pollution followed guidelines outlined in APHA, 2005. This was done within 6-24 hours after sampling to avoid changes of the bacteria count due to growth or die off. Aseptic techniques were observed in all the analysis. Membrane Filtration Technique (MFT) *(Appendix 1)* was used in the analysis of samples for the presence of bacterial indicator organisms (*Escherichia coli, Faecal streptococci*, *Salmonella typhi* and Total coliform*)*. For individual samples collection, a 100ml bottle was filled three quarter way with sample then capped immediately, labelled, safely stored in sampling kits at cool temperatures of below 4° C and transported under safe conditions for immediate laboratory analysis. Microbiological water quality analysis of samples was done at the Egerton University's Limnology laboratory.

Under the Membrane Filtration Technique, aseptic filtration was done separately for each dilution by passing the sample through a membrane filter (47mm diameter, 0.45ìm pore size) on a filtration unit. The filter was taken off using a pair of forceps and placed on the surface of the corresponding culture media (APHA, 2005).



a) Sampling at dug outs water fetching points in Isiolo River b) MFT Technique c) *E. coli* (blue colonies) and Total coliform (pink colonies) d) *F. streptococci* and e) *S. typhi* plates

Plate 1: Sampling and laboratory analysis techniques

For Total coliforms and *E. coli* counts, filters were placed onto Chromo-cult agar (Merck) plates and incubated at 37^{0}C for 18-24 hours. Typical colonies appearing pink and dark blue as in plate 1 (c) were counted as Total coliforms. *E. coli* were the blue colonies only. Numbers of cells were expressed as CFU's /100ml (APHA, 2005). For *Faecal streptococci* counts, filters were placed onto CLED media (Merck) plates and incubated at Culture medium: CLED Media at 18^{0}C for 18-24 hours. Typical colonies appearing Yellow colonies (0.5mm diameter) as in plate 1 (d) below were counted as intestinal enterococci and numbers expressed as CFU's /100ml. For *Salmonella typhi*, filters were placed onto SS Agar (Merck) plates and incubated at 35^0c for 24-48hrs. Typical pink colonies with dark spots as in plate1(e) below were counted as *Salmonella typhi* and were expressed as CFU/100ml as stipulated in (APHA, 2005).

3.8 Validity

Validity is the amount of systematic or in-built error in measurement (Norland, 1990). Both face and content validity of the questionnnaire was conducted by appointed experts and the researcher who determined that it measured the characteristic of interest. Verification of information from household respondents to ascertain that all the questions are answered correctly and consistently during questionnaire administration was also done.

3.9 Reliability

Reliability is a measure of the degree to which a research instrument yields consistent results or data after repeated trials under similar situations (Mugenda A.G., 2005; Mugenda, O.M., 2005). Reliability of a questionnaire tool often measures whether it is comprehensive enough to collect all the information needed to address the goals and purpose of the study. This involves systematic development of the questionnaire to reduce measurement errors in content, respondent, design and format (Norland, 1990). Prior to the research, a pilot study was conducted through pre-administration of twenty questionnaires to household respondents in Waso ward in Samburu County. During the pre-test, it was noted that there was adequate conceptualisation of the questionnaire by the respondents. The test for reliability of the questionnaire was conducted using the Cronbach's alpha in SPSS statistics. A Cronbach's alpha of $r=0.85$ ($P<0.05$) was realised yielding a high level of consistency, thus sufficiently reliable.

Reliability of laboratory methods was achieved through performing repeated bacteriological analyses tests for water samples from River Njoro and Egerton University tap water supply using the membrane filtration method. On average, the bacterial counts for *E. coli* and Total coliforms in the river sample were 2.5×10^3 CFU and 8.0×10^3 CFU /100ml respectively. The tap samples however indicated lower bacterial counts of *E. coli* and Total coliforms at 0.1×10^1 CFU and 2.0×10^1 CFU/ 100ml. From the results, it was observed that the river water was more microbiologically contaminated than the tap water samples. The experimental method of analysis was found to be efficient enough to yield sufficient reliability.

3.10 Data analysis

A normality test of the data on was done using Kolmogorov- Smirnoff test. Homogeneity of variance was tested using Levene's test. The tests revealed that the data was normally distributed. Data was managed using SPSS and all tests performed at 95% confidence level. Household data on faecal disposal practices and water handling practices was analysed using descriptive and inferential statistics involving frequencies and means. Pearson's test for correlation was also used to compute whether there was significant association between the various selected variables. Analysis of variance (ANOVA) was performed to test if there was a significant difference in the mean counts of bacterial parameters namely *Escherichia coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliforms. All the tests were performed at 0.05% level of significance. Table 3 shows a summary of data analysis.

Table 3: Summary Table on Data Analysis

No.	RESEARCH QUESTIONS	VARIABLES	STATISTICAL TOOL(S)
1	What are sanitation characteristics in open defecation free and open defecation not free areas in Isiolo County?	Faecal disposal practices	Descriptive statistics
2	What are the drinking water sources used by the residents of Isiolo County?	Drinking water sources	Descriptive statistics
3	What are the household water treatment and handling practices by the residents of Isiolo county?	Water treatment practices Water quality	Descriptive statistics Pearson's Correlation
4	What are the comparison levels of *E. coli*, *Faecal streptococci*, Total coliforms and *Salmonella typhi* between the various samples?	Concentrations of *E. coli*, *Faecal streptococci* *Salmonella typhi*	Descriptive statistics ANOVA
5	What is the spatial distribution of open defecation points and latrine coverage in the study area.	Number of open defecation points and percent latrine coverage	Descriptive statistics

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Household socio-demographic data

In the crossectional study, 150 households were sampled. Household interviews and questionnaire administration in households was conducted giving preference to the household head. A greater percentage (72%) of the household respondents were females (n=108), while the males were 42 (38%) of total respondents. Majority of the households interviewed (65%) had between 10-15 members on average. According to findings during the household interviews, women were found to be better placed in responding to water issues at the household level since such falls in their domain. The education levels of household heads was sought and presented as follows in Table 4.

Table 4: Highest education levels attained by household heads

Education level	No. of respondents (n)	Percent
No formal education	100	67%
Primary education	36	24%
Secondary education	11	7%
Tertiary	3	2%
Total	**150**	**100%**

As presented in Table 4, the number of household heads with no formal education was high at 67%. Majority of them equally reported being not able to read and write. The findings are consistent with the 2009 census report that depicted high illiteracy levels in the county compared to the national averages (GoK, 2010). According to the Kenya National Adult Literacy Survey (KNALS) conducted in 2006, Kenya has a national adult literacy rate of 61.5 per cent (KNBS, 2010). The level of education of the household head had a direct bearing on the health related decisions made for the household as well as adoption of good latrine related practices. This was demonstrated by the absence of latrine facilities in 75% of the households in which the head had either primary and no formal education.

The various income sources among the households under study were assessed (Table 5). Livestock keeping (pastoralism) was found to be the key means of livelihood for the households interviewed. This scenario meant that women, children and elderly were predominantly left to attend to household duties while the men move with cattle to look for grazing pastures.

Table 5: Respondent's source of income

Occupation	No. of respondents(n)	Percent
Livestock keeping	74	49%
Small-scale Farming	6	4%
Casual employment	9	6%
Salaried employed	5	3%
Trading	37	25%
Artisan	3	2%
Un-employed	16	11%
Total	**150**	**100%**

4.2 Assessment of sanitation status

4.2.1 Latrine presence in ODF and Non-ODF areas.

In order to ascertain the faecal disposal characteristics in Open defecation free (ODF) areas and Open defecation not free (ODNF) areas, latrine coverage was assessed. The study revealed a marked disparity in latrine coverage in both the ODF and the ODNF areas (Figure 6). Out of the 75 households sampled from the ODNF villages, only 23 (31%) had access to latrine facilities while among households in ODF villages, 56 (75%) households had access to latrine facilities.

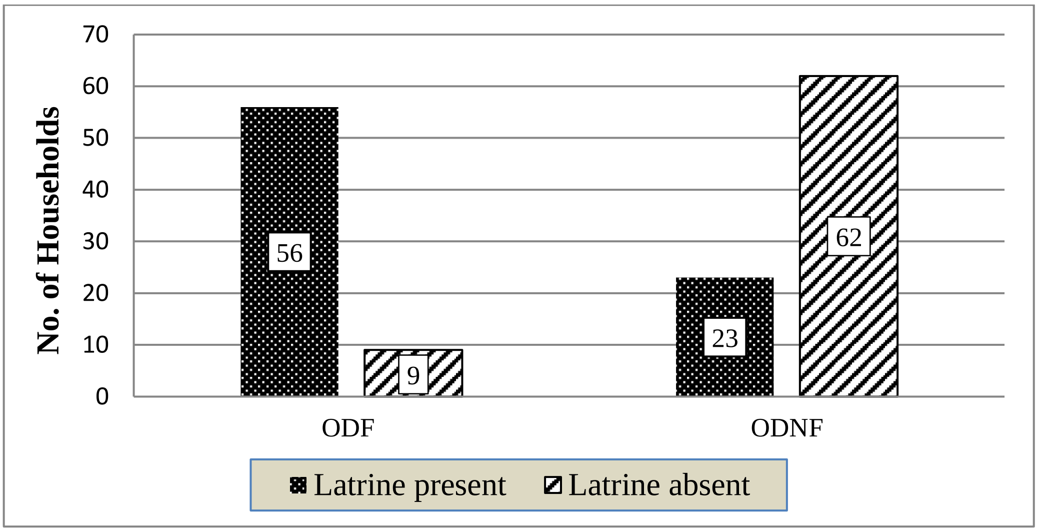
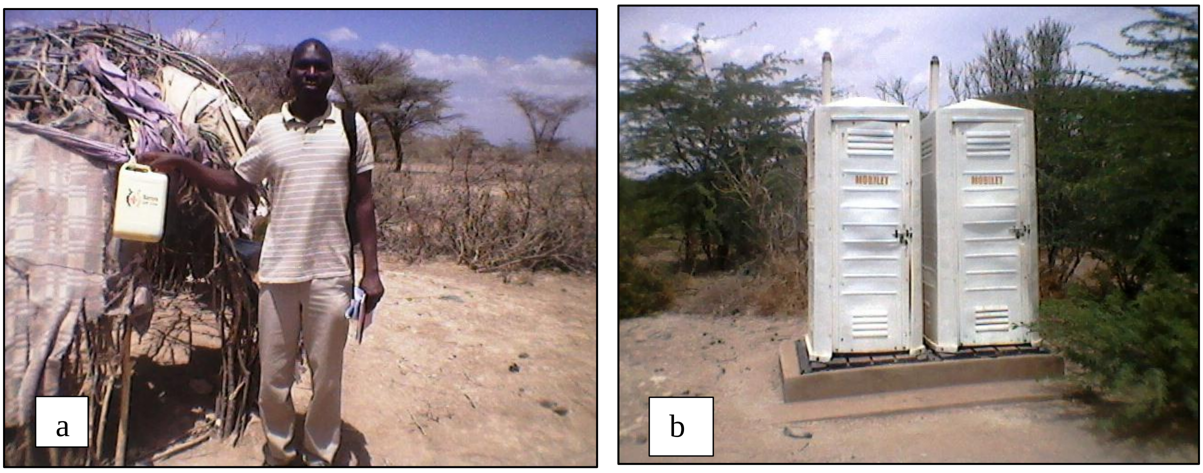


Figure 6: Latrine coverage between ODF and ODNF areas

The findings above indicate a marked improvement in latrine presence in open defecation free areas as compared to open defecation not free areas. This can be attributed to increased efforts of CLTS in these areas aimed at ensuring that each household has access to a latrine facility. The importance of hand washing facilities in Community Led Total Sanitation (CLTS) initiatives has been recognised (Mehta and Movik, 2010). Despite access to latrine facilities, their use by individuals was limited to sanitary condition of the facility, hygienic use by other latrine users.

Hand washing facilities in latrines was present in 78% of households in ODF areas while in latrines in ODNF areas only 27% of latrines had such facilities. In order to determine preference for latrine use, 65% households sampled in ODF areas reported using latrine facilities compared to 17% in ODNF that did not use to such facilities. The presence of hand washing facilities around latrines improves hygiene by ensuring that transfer of faecal microbes does not take place through contaminated hands (Luby *et al.*, 2011). Plate 2 demonstrates open defecation eradication efforts in Ngare Mara, Isiolo County.



a) A hand washing facility present at a latrine b) Community pit latrines

Plate 2: ODF verification in Ngare Mara ward (Source: Author)

4.2.2 Sanitation modes among households

In order to determine latrine use among household members, the sanitation modes available to households was assessed. According to the findings of the research, it was found that on average, a single latrine was shared between 8-10 households in 68% of the households. This was found high considering that each household had an average number between 10-15 individuals. A high user degree of a single latrine has been shown to have health implications. Gunther *et al.,* (2011) explains that large numbers of users often do not seem to be capable of properly maintaining a sanitation facility, and when this happens, there is a large probability that people will resort to open defecation. According to Roma *et al.,* (2010), as the number of users of a latrine increases the proper maintenance, hygiene, privacy and safety of the users are not always guaranteed. A Joint Monitoring Programme (JMP) report on proposals to define the Post-2015 MDG goals and indicators for sanitation, recommends that improved sanitation be shared among no more than 5 households or 30 people (WHO/UNICEF, 2010). A research by

Gunther *et al.,* (2011), however recommends that not more than four households (or 20 individuals) should share a toilet stance to ensure long-term hygienic and sustainable use. Figure 7 gives the percentage of households using improved and un-improved latrines.

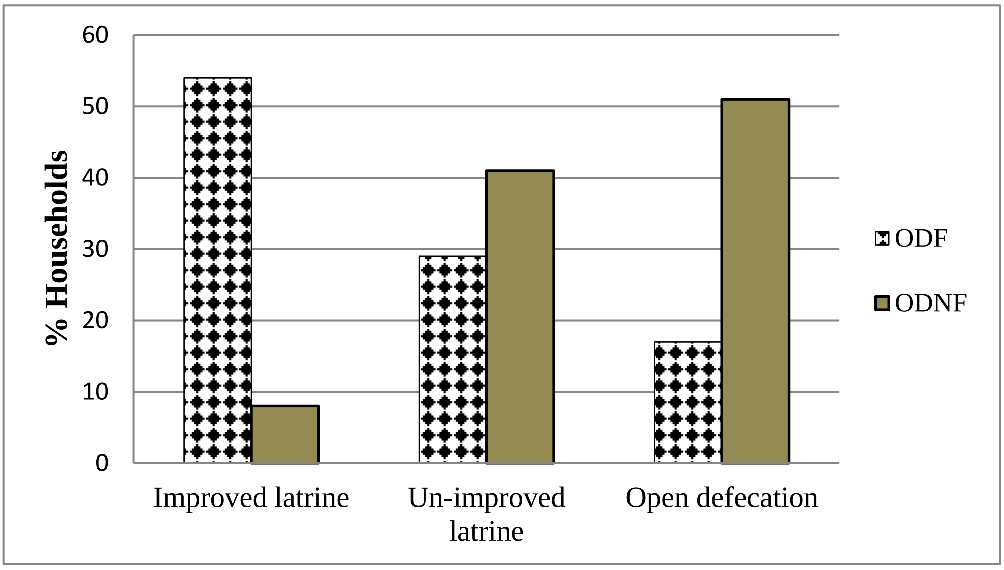


Figure 7: Graph of sanitation modes in ODF and ODNF areas.

The findings above indicated that open defecation free areas had a higher propotion of households using improved latrines as compared to open defecation not free areas. The role of external actors especially NGOs in promoting latrine use was noted to be significant. In this study, provision of subsidy for latrine construction was categorized as any form of assistance provided to a household in the form of finances, labor or technical support as well as provision of latrine construction materials. Majority of the respondents in the study area attributed availability of improved latrines to external support mostly from NGOs and increased awareness efforts. Studies have indicated that the presence of an improved latrine facility in a household can lead to a marked reduction in child diarrhoea (Semba *et al.,* 2011: Clasen, 2014).

4.2.3 Faecal disposal among households

The research findings as in Figure 8 indicated that faecal waste among the residents was disposed using simple pit latrine (64% ODF and 33% ODNF), ECOSAN toilets (10% ODF and 5% ODNF) and VIP latrines (6% ODF and 3% ODNF). This trend was found to affect the open defection tendency among households, with the practice being rampant among households with no access to latrines.

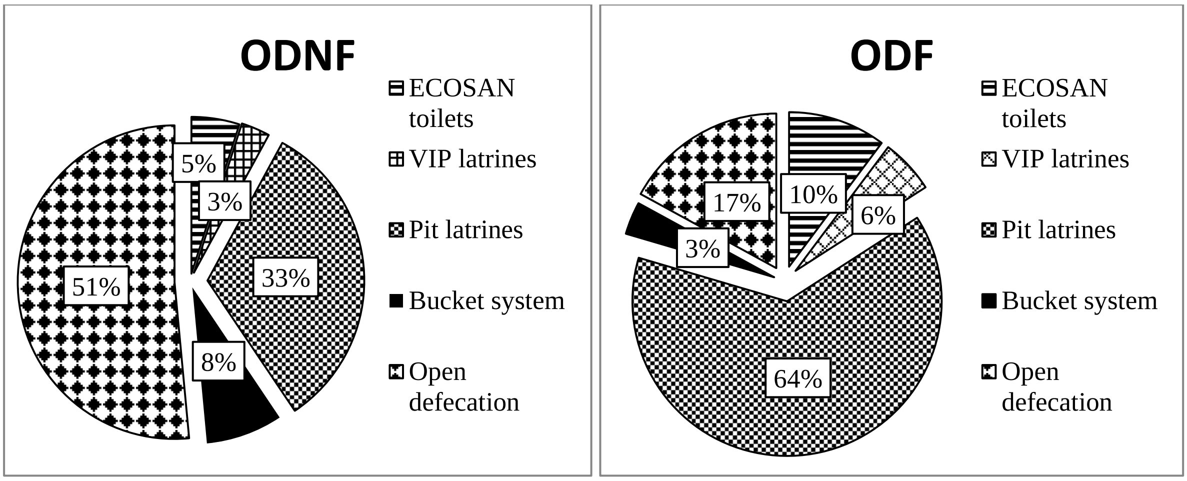


Figure 8: Sanitation types among ODF and ODNF villages

The findings above also indicate that open defecation was the most prevalent form of faecal disposal among the households in ODNF areas whereas in ODF areas there was marked improvement in faecal disposal through use of pit latrines. Pit latrines were preferred by the households because of being the simplest and convenient form of sanitation. A toilet or latrine is often considered the most important sanitation facility in a household and is preferred by many communities (Jenkins and Scott, 2007). A study conducted in four districts of Ghana however revealed that most people wanted toilets for reasons of convenience, privacy and status rather than ensuring a healthy environment, good sanitation or the prevention of diseases such as diarrhoea, cholera and malaria (Boateng *et al.*, 2013). According to Shakya *et al.* (2015), efforts aimed in ensuring access to latrine facilities is the modest step to eradicating open defecation practice. An assessment to compare the proportion of households with improved versus un-improved sanitation conditions was conducted (Figure 9).

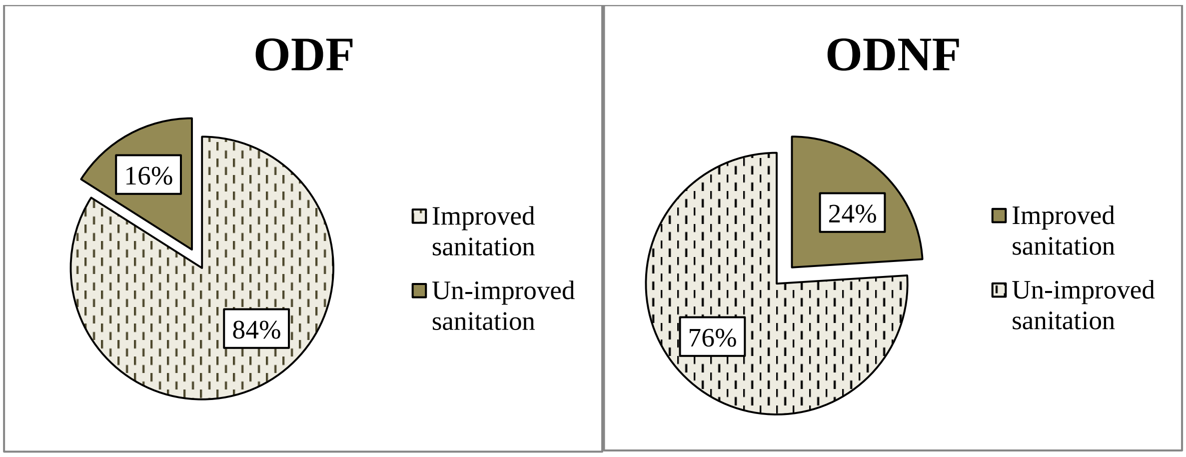


Figure 9: Sanitation conditions in ODF and ODNF areas

The findings above indicate that households in ODF areas had higher percentage of improved sanitation conditions (84%) compared to households ODNF areas (24%). This can be explained by the increased CLTS campaign initiatives aimed at increasing the number of households practising safe disposal of excreta. The importance of community led initiatives in promoting safe disposal of human excreta has also been recognised (Chambers, 2009). Un-improved sanitation modes included unsafe faecal disposal practices among the households such as open defecation in nearby bushes (67%), use of plastic bags (2%) and digging holes (31%) for immediate use. Open defecation as a method of faecal disposal poses a risk to human health because it introduces faecal matter to the environment and prone to being carried away as run-off into to water sources leading to contamination (Galan and Graham, 2013). In a research conducted to assess open defection practices in Tamale Metropolis, Ghana it was revealed that defecation in plastic bags and throwing into the bush, gutters and backyards was is rampant. This trend had a double pollution impact on the environment from plastic bags and human waste (Boateng *et al.,* 2013).

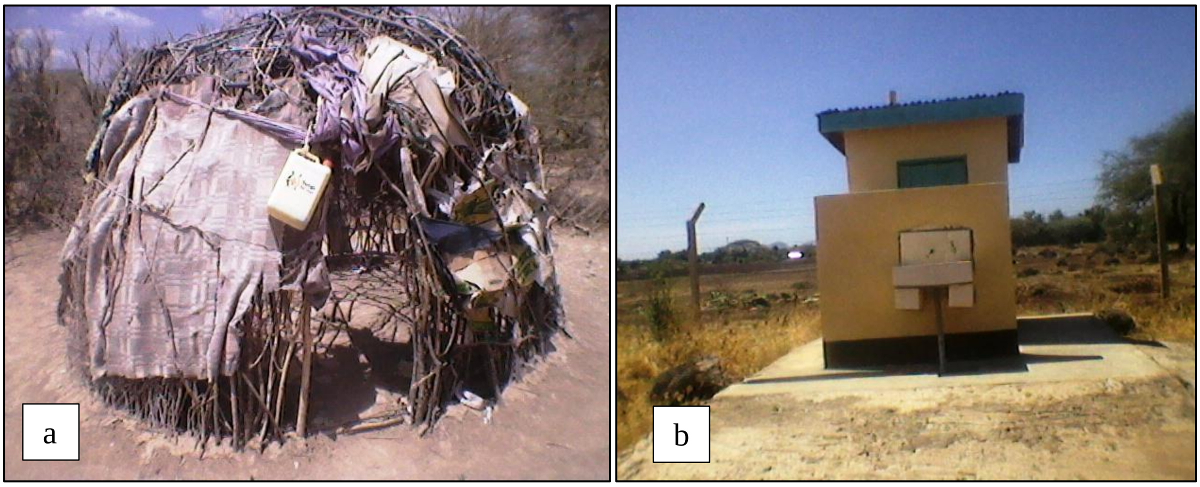
4.2.4 Respondent's perception on conditions of latrine facilities

The respondents' were asked to state their perception on the conditions of their latrine facilities (Table 6). Only 31% of the respondents reported their sanitation facility to be in a reasonable condition. It was noted that poor latrine conditions discouraged the use of such facilities, prompting open defecation. Women in particular had a problem using latrine facilities in unhygienic conditions with 56% indicating they were un-comfortable using such.

Table 6: Conditions of sanitation facilities among households

Condition of Facility	Frequency (n)	Percent (%)
Latrine full	9	6
Dirty/ smelly	23	15
Dilapidated walls/ roofs	51	34
Inadequate size	9	6
Unstable/ collapsed	12	8
Facility in good Condition	46	31
Total	**150**	**100**

Sharing of sanitation facilities among several households was found to have an impact on the hygiene of the facility. The research revealed that a single latrine was being shared by up to 30 members. According to a research on shared sanitation versus improved sanitation in Ghana, it was revealed that there is a clear and strong correlation between number of users and the condition and cleanliness of a toilet stance (Gunther and Fink, 2010). Plate 3 shows various types of latrine facilities observed.



a) A pit latrine in Ngare Mara A village b) A VIP latrine village in Kilimani village

Plate 3: Types of sanitation facilities observed (Source: Author)

4.2.5 Child faeces disposal practices

The disposal of children faeces is considered as very important sanitation and hygiene practice. A child's faeces contain as many germs as an adult's and it is very important to dispose the faeces quickly and safely. During the study, 68% of the households interviewed had children under the age of five years. The child (under-five age) faeces disposal techniques in the households have been presented in Table 7.

Table 7: Child faeces disposal techniques among households

Disposal technique	Number (n)	Percent
Burying	24	16%
Leaving in open to dry	54	36%
Toilet disposal	17	11%
Disposing in the bush	48	32%
Do nothing about it	7	5%
Total	**150**	**100%**

In most times, the child faeces remained un-disposed in the environment for long periods or not disposed at all since it was perceived as less harmful. However, child faecal matter has been known to carry the highest concentration of bacterial pathogens. This is because small children have a drive to play and explore, they are in close contact with the ground and they have little appreciation of hygiene; they are more likely to come into contact with excreta, the primary source of diarrhoeal disease and intestinal parasites, as well as other pathogens (Bartlett, 2003). These findings were found to be consistent with those in a study conducted in rural districts of Tamil Nadu, India to assess open defecation awareness and practices. According to the findings of this study, the respondents were found to dispose of the children's faeces in garbage pits, in the toilets, in the streets and in drainage (Geetha and

Kumar, 2014). A study to determine factors associated with safe child faeces disposal practices in Ethiopia, revealed that the odds of safe disposal of child faeces was influenced by mother's level of education and place of residence (Azage and Haile, 2015).

4.2.6 Factors that influence latrine use

Certain conditions were found to influence latrine use and consequently necessitate the practice of open defecation within households. The absence of latrine facilities was widely noted as the reason for engaging in open defecation. In particular, 43% of the households indicated they were forced to open defecate because they could not access latrine facilities, 32% indicated it was due to ignorance while 25% indicated that it was the cultural lifestyles. Low latrine use among the respondents could also be attributed to their nomadic nature of life. In some cases, the privately owned latrines were kept under lock at most times by owners, hence not easily accessible. The respondents also cited long queues in order to use latrines as a hindrance to shared latrine use. This scenario could force some individuals to engage in open defecation at some hidden locations such as nearby bushes. According to Boateng *et al.* (2013), in a research done on implications of open defecation in Ghana, it was observed in the study that indiscriminately defecating openly have negative health implications in the lives of the people especially women and children.

To determine latrine access to households, the respondents were asked to state their inability to access latrine facilities. The responses were presented as in Figure 9.

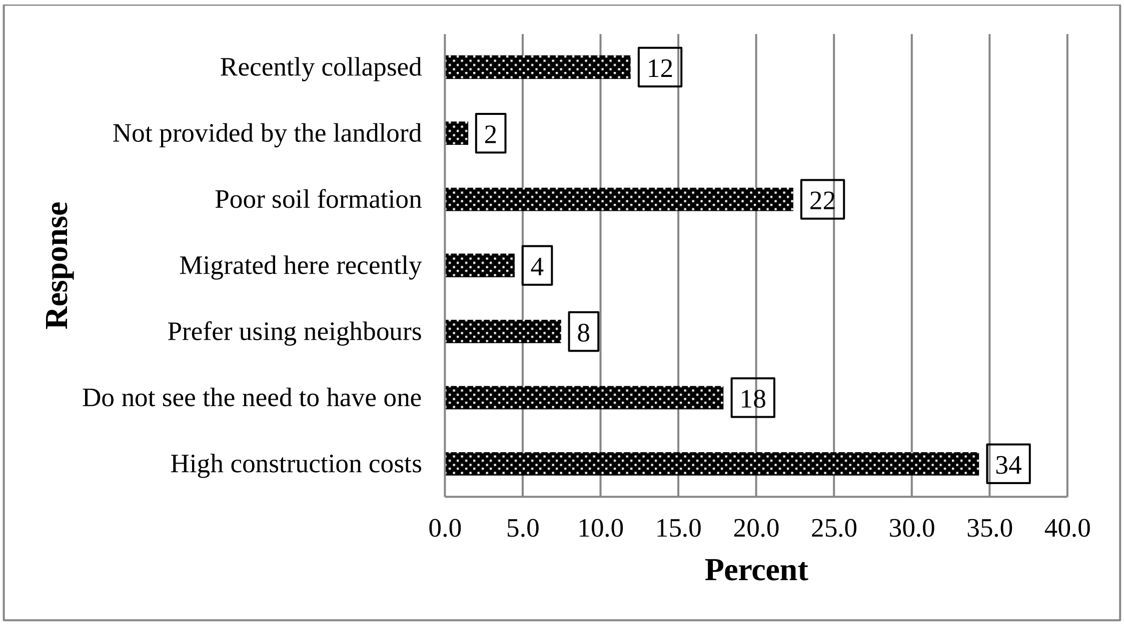


Figure 10: Reasons for inaccessibility to latrines by households

The findings indicate that majority of the residents cited high construction costs as a barrier to toilet construction. A study conducted in rural districts of Tamil Nadu, India to assess open defecation awareness and practices cited cultural barriers, incomplete knowledge and water scarcity as reasons behind not using toilets. The most quoted reasons for not constructed toilets was non availability of funds and few attributed to no space in their houses while rest due to cultural barriers (Geetha and Kumar, 2014). The construction of toilets was generally seen as a responsibility of the government.

According to Galan and Graham (2013) access to a toilet does not always mean it is used or maintained. Ownership of a toilet does not always lead to better adoption of sanitation and hygiene practices. Often faulty design, lack of proper maintenance, lack of knowledge about proper toilet usage and insufficient running water in the vicinity raises dissatisfaction levels, resulting in open defecation. Thus, along with highlighting the relevant benefits of constructing toilets, there is an urgent need to provide information about the availability of improved and affordable design options and how these can easily be maintained.

4.3 Water supply situation and water handling practices at household

The various types of water sources relied upon for drinking purposes was sought. Figure 11 shows various sources relied upon by households for drinking purposes. It can be noted that majority (52%) of the households sampled rely on shallow hand-dug wells for their drinking water purposes.

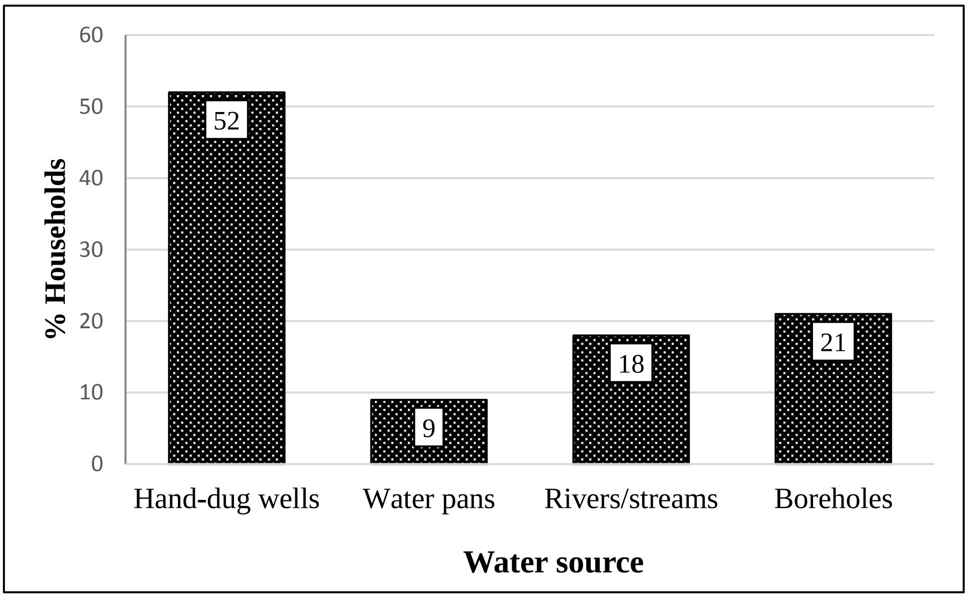


Figure 11: Water sources relied on by households

The study results also revealed that the drinking water sources relied upon by households were in most cases un-protected. In general, it was found out that 68% of the households relied on unprotected water sources such as water pans, hand-dug wells and stream water sources while only 32% of the households sampled relied on protected water sources majorly boreholes.

a) Women withdrawing water from dug-outs in Burat b) A hand-dug (rope withdrawal) well in Ngare Mara

Plate 4: Some water sources accessed by households (Source: Author)

Health implications of relying on un-protected water sources especially for drinking have been documented. Hazra (2013), states that unprotected water sources can easily become contaminated and unfit for drinking. A study conducted in Orrissa, India associated cholera outbreak in children to use of un-protected sources for drinking purposes (Das *et al.*, 2009).

4.4 Water access

4.4.1 Distance to water source

The distance covered to fetch drinking water varied from one water source to another from the households as indicated in Table 8.

Table 8: Distance covered to water source

Distance to water source	Percent HH (%)
Less than 500m	24
500m-1km	20
1-2km	54
2-5km	2
Total	**100**

The findings indicate that 54% of the drinking water sources were located within 1-2 km from household. Long transportation distance pose a risk to contamination of fetching containers as they are placed down over resting intervals in the course of delivery to households. The long distance covered to access a water source was found to increase the reliance on un-safe water sources. This was true for a survey study on household domestic water consumptions in rural semi-arid village, India which revealed that most households prefer to use water of poor quality that that is found closer to their homes to travelling long distances to or spending extra time at the water sources to obtain good quality water (Singh and Turkiya, 2013).

4.4.2 Time taken to collect water

Women and children in low-income countries are the main water carriers and spend, on average, one hour per trip collecting water, with several trips required per day (Sorenson *et al.,* 2011). On average, most (58%) individuals stated it took them 1-2 hours in fetching water, 24% took between 30 minutes -1 hour, while 18% stated they took less than half an hour on one trip. According to World Health Organization, water collection time should not exceed 30 minutes (WHO, 2012). Time spent in walking to the water source is reported to influence water quantity and quality (Kayser *et al.*, 2013). As travel time to the water source increases, there is a reported decrease in water carriage to the household and this can be associated with insufficient consumption and hydration. Water quality deterioration is also associated with increased collection time since contamination may occur during collection, transport and storage. This may explain the findings of recent research on effects of water fetching distance on child health in Africa, which points to less diarrheal disease as time to fetch water decreases (Pickering and Davis, 2012). In another study carried out in rural areas of Nepal by Doron and Raja (2015), it was revealed that rural people use the most convenient sources of water in their areas irrespective of quality in order to save time for other activities.

4.4.3 Water fetching times

In order to assess the water fetching trends, the respondents were asked what time of day they preferred to withdraw water from the source. Forty three per cent preferred morning hours, 15% preferred evening, 10% preferred daytime while the other 32% confirmed they had no specific time for withdrawing water from the source. Majority of the respondents considered fetching water in the morning safe because they felt the water was least disturbed. Other respondents felt the weather conditions were favourable at this time, while some preferred morning time so that they could engage in other activities of the day. In a study conducted to establish the disturbance of River Njoro, in Nakuru County, by the daily activities of local people and their livestock, Mathooko (2001) notes that, abstraction trends tend to vary across different times of the day. He notes that women mostly fetch water for household use predominantly in early morning and late afternoon hours, and that during midday, disturbance activities from children and animals visiting the stream were high and consequently affecting stream water quality.

4.5 Drinking water treatment and handling at household

To determine the various drinking water treatment methods used by households, the respondents were asked to state their preferred treatment methods. Only 47% of the respondents admitted subjecting their drinking water to atleast some mode of treatment as indicated in Table 9.

Table 9: Drinking water treatment methods at household

Treatment method	Percent	Respondents (n)
Chemical	18%	27
Filter	16%	24
Boiling	6%	9
Leave to settle	4%	6
Solar disinfection	3%	4
Do not treat	53%	80
Total	**100%**	**150**

The findings reveal that in determining the preferred treatment method, the residents employed less costly and less time consuming methods. The findings are similar to those of study conducted by Balasubramanian, (2013) in Krishnagiri District of Tamilnadu, India on sanitation stategies for water quality management. This implies settling for less effective methods of drinking water treatment such as leaving water to settle and this could have associated health impacts due to taking improperly treated water. To determine factors influencing water treatment, respondents asked to state reasons why they did not consider treating their drinking water. The responses were presented as in Figure 12.

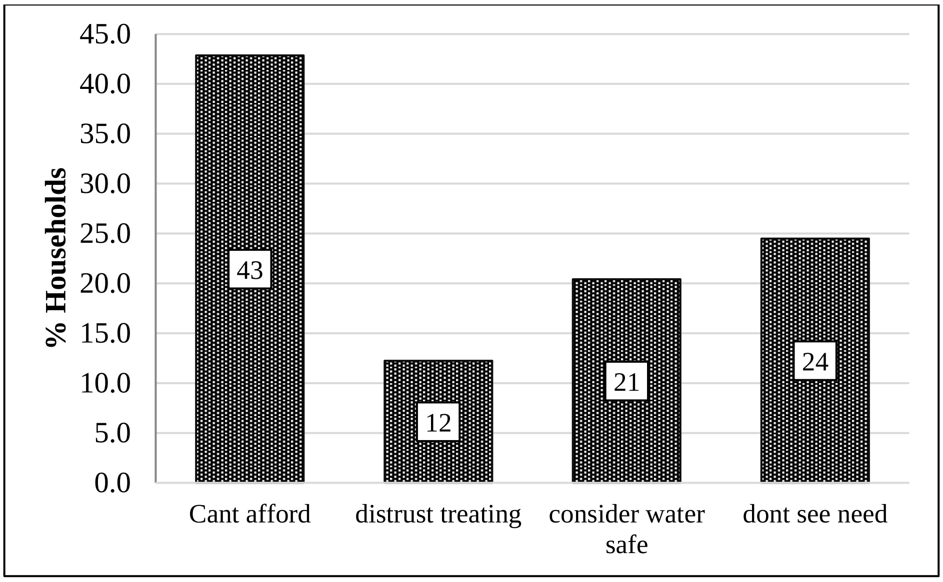


Figure 12: Respondents' reasons for not treating drinking water

From the above responses, it can be concluded that water treatment was merely pegged on an individuals' perception and attitude. In some cases the argument being that consuming water raw from the source untreated was wholesome and that treating it would either destroy its flavour and in some cases introduce harmful chemicals to it. Huber and Mosler (2013), however in a study in rural Ethiopia demonstrated that behavioural factors can be used to influence safe water consumption. In the study, they found out that the introduction of community filters was widely accepted and this helped improve peoples' perceptions regarding distance, taste, knowledge, habit and commitment. This helped to increase fluoride free water consumption among the community. The respondent's perceptions of safe drinking water was determined and presented in Table 10.

Table 10: Respondents' perception towards safe water

Perception	Percent respondents (%)
Colour of the water	48%
Taste (i.e. Salty)	23%
Suspended solids	19%
Odour	4%
Source of water	6%
Total	**100%**

The above responses indicate that the perception by households on drinking water safety was majorly based on physical parameters. Though water may appear clear, colourless and odourless, it is important to treat the water before drinking and know its source and ensure that it is stored safely. Only 6% of the respondents seemed to have the correct knowledge (i.e.

those who stated boiled water) while 92% were at risk of drinking unsafe water. In a similar study conducted to assess household attitudes and knowledge on drinking water in peri-urban communities in Western Kenya, it was found that only 3% of the households boiled their drinking water and assumed that water which was clear, colourless and odourless and contained no suspended solids was safe for drinking and therefore it was not treated (Kioko and Obiri, 2012). The level of knowledege an individual had received was found to determine perceptions and attitude towards safety of drinking water in households. Similar findings have been put forward by Boateng *et al.*, (2013) in their study to establish the determinants of water quality in Tamale Metropolis in Ghana.

4.6 Household drinking water storage

4.6.1 Choice of drinking water container in households

Because of the non-availability of a constant provision of water for households, individuals tend in one way or the other to store water in containers for future use. During the study it was found, that majority of the households (64%) preferred using pots and buckets while the rest stored water in jerricans and bottles. The reasons determining the choice of water storage container have been indicated in Table 11.

Table 11: Reasons for container preference

Reason for container preference	Percent
Ease of drawing water	12%
Ease of the container cleaning	11%
Affordability of storage container	20%
Water safety factors	25%
Cooling aspects	32%
Total	**100%**

The results suggest that community attitudes towards choice of water containers were not based on safety. This is because the bottles and narrow-necked containers (which offer more guarantee against contamination) could still keep water cool by placing them on the ground or floor inside houses. Indeed, Crampton (2005) showed that the safety of water stored in a narrow-necked vessel was higher than in wide open-mouthed vessels like buckets because contamination through dipping in smaller vessels like cups and jugs was minimised.

4.6.2 Frequency of cleaning container

To determine cleanliness of water storage containers, the respondents were asked to state the frequency of cleaning their water storage containers. The responses have been presented as in Figure 13.

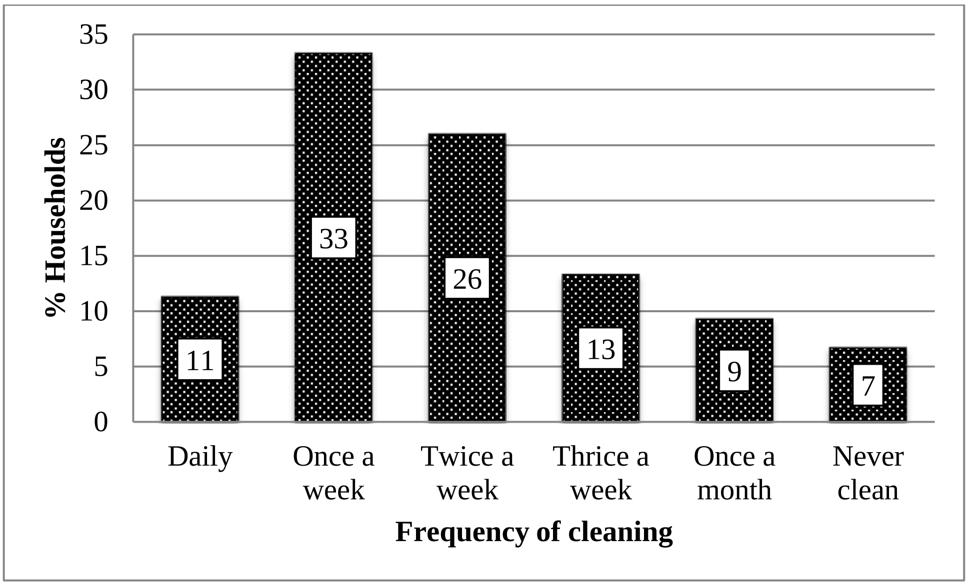


Figure 13: Container cleaning among households

The study revealed that many residents preferred to clean their storage containers only when dirty. The findings are consistent with a study conducted to assess water and sanitation hygiene, knowledge, attitude and practice in urban slum settings, which found that the frequency of cleaning container was pegged on the level of dirt it had gathered (Joshi *et al.*, 2014). Cleaning of safe storage units on a regular basis is necessary to reduce the likelihood of contamination associated with storage (Stevenson, 2008).

The research also revealed that 54% of the residents used the same container for fetching and storage, while 46% of the respondents used different container for storage purposes other than that used to fetch water. Using the same container for fetching water and for storage purposes is likely to introduce contamination into the drinking water especially due to poor handling during fetching (Katuwal *et al*., 2015). Stevenson (2008), in a study aimed at monitoring effective use of household water treatment and safe storage technologies in Ethiopia and Ghana, advocates for safe storage of water containers. He particularly notes that containers used to fetch water are potentially contaminated compared to storage vessels. A user must procure an appropriate storage container separate from the container used to collect water.

4.6.3 Covering of drinking water containers

According to the study 19% of the households covered their drinking water vessel using plate, 21% using clothing, 13% using container lid while 47% of the households did not use any covering. Among the households that covered their drinking water, it was found that 52% of the container lids observed were dirty due to constant touching while fetching water. Water vessel if left un-covered could be prone to dirt from surfaces within the house and even wind-blown dust from outside which in most cases contains dirt (Rufener *et al.,* 2010). Diarrhoeal diseases have been associated associated with not covering the water storage container. For instance, in a case-control study in a poor urban settlement in South Africa (cases of diarrhoea reported at Medicines du Monde clinic), it was observed that 74% of case households stored water in open containers as opposed to only 54% in control households (Jagals, 2006). Furthermore, although water supplied was of similar quality (Geometric Mean, 2 FC (Faecal Coliforms)/100 ml), stored water in case households was found to be highly contaminated with a geometric mean of 1,207 FC/ 100 ml, versus 6 FC/ 100 ml in control households.

4.6.4 Storage place in the house

The research results indicated that in 40% of the households, drinking water was stored in the living room, 38% stored in kitchen, 9% in the bedroom area while 13% did not have a specific storage area. Water storage practices had a potential of determining how safe the water was. Storing of water in places where it could easily be accessed exposes it to vulnerability of contamination especially by children who in most cases access the place with dirty hands (Clasen and Bastable, 2003). A study aimed at monitoring effective use of household water treatment and safe storage technologies in Ethiopia and Ghana found that in nearly 80% of the households, drinking water was stored at safe locations within the households. It was observed that the households considered factors such as inside house storage, direct sunlight, off the ground, stable situation and out of reach for animals and small children as those determining safe storage of containers (Stevenson, 2008).

4.6.5 Water fetching practices from containers

The study results indicated that 64% of the households studied stored drinking water in wide-mouthed containers such as buckets and pots. The wide mouth containers were considered an easy access during fetching especially for children who are most likely to pour the water out during tilting as in the case of narrow mouth containers. However, wide mouth containers have been proved to enhance contamination because of their large surface area (Kioko and Obiri, 2012). In a study conducted to assess the Epidemiology of Waterborne

Diarrhoeal Diseases among Children Aged 6-36 Months Old in Busia, Kenya, it was found that Water storage facilities especially with wide brim and without cover was highly associated (Pearson's correlation 0.12, $P \leq 0.05$) with occurrence of diarrhoeal diseases in children (Onyango and Angienda, 2010). These results are consistent with previous studies showing that factors related to the container, such as large versus small mouth and covered or uncovered, are key factors in determining quality of stored water (Eshcol *et al.,* 2009). Using a tap or spigot to access water is protective of stored water quality compared with water in which access was obtained by dipping or pouring (Clasen and Bastable, 2003).

To determine hand cleanliness, only 29% (n=44) respondents admitted they did wash their hands before fetching accessing drinking water from storage vessel, while 71% (n=106) of respondents admitted they did not. Sixty three percent (63%) claimed that they always used soap, 21% used it occasionally, and 16% never used soap. The latter group stated lack of money for buying soap as the reason for not using soap. Lack of hand washing after toilet use has been linked to contamination of water as bacteria can move from the hands into the water (WHO/UNICEF, 2011). Though hand washing after toilet use is an important positive hygiene practice, it is important that it is done with soap and running water to ensure that the germs are removed. A similar study on effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminthic infection, and child malnutrition in Odisha, India revealed that 50% of households surveyed knew that water contamination causes diseases, however 64% of these households continued to draw water from storage vessels by inserting a hand. Although 92% of respondents considered washing hands to be important for personal hygiene, only in 29% households had soap/ ash kept at the washing area (Clasen *et al.*, 2014).

To determine fetching practice, 52% of the respondents also admitted they obtained water from storage vessel by dipping, 45% obtained by pouring while 3% ad spigot containers. Bain *et al.* (2014), in a study conducted to assess household drinking water safety in households, warns of the dangers of relying on dipping method of fetching water especially when containers used have no handle at all. This is because it was found to increase the risk of contamination on drinking water considering that most residents especially children, did not wash their hands after visiting latrines or in some cases use soil to clean their hands. In another study, it was discovered that using a tap or spigot to access water is protective of stored water quality (Clasen and Bastable, 2003). This is after an arithmetic mean (TC count = 97) was recorded for spigot or tap use compared with water in which access was obtained by dipping (TC count = 252) or pouring (391).

4.6.6 Water quantities used in household

To determine the per capita water use per individual, the respondents were asked to state the average quantity of water used in the household as presented in Table 12. On average, majority (46%) of the households utilised between 20-40 litters of water on a daily basis for household water needs.

Table 12: Quantities of water used daily per household

Water quantity (Litres)	% Households
0-20	17%
20-40	46%
40-60	25%
60-80	8%
Above 80 litres	4%
Total	**100%**

The Average per capita water consumption for majority of the households studied was 15.1litre/person/day. This was found to be below thw World Health Organization (WHO) recommended minimum of 20 litres of water per capita per day that is needed to meet the requirements of a single individual and 100 Litre of water per person per day is optimal to ensure that consumption and hygiene needs are met (WHO/UNICEF, 2011). Sufficient water for hand washing, hygiene, and bathing can reduce the spread of water-washed diseases including those spread through the faecal-oral route, as well as skin and eye diseases (Kayser *et al.*, 2013).

4.7 Water-related diseases infection and hygiene education amongst households

In order to determine waterborne disease infection in households, the respondents were asked whether they had suffered from any water borne disease over the past 6 months (Figure 14). From the findings, diarrhoeal infections recorded the highest number of water and sanitation related complications (31%) infections over the past six months. The respondents stated they attributed the infections to be as a result of faecal-oral exposure (33%), taking contaminated water (48%) and poor hygiene (19%). According to 54% of the respondents interviewed, the high infection rates from waterborne diseases can be attributed to poor sanitation conditions in the environment which result in contamination of drinking water sources.

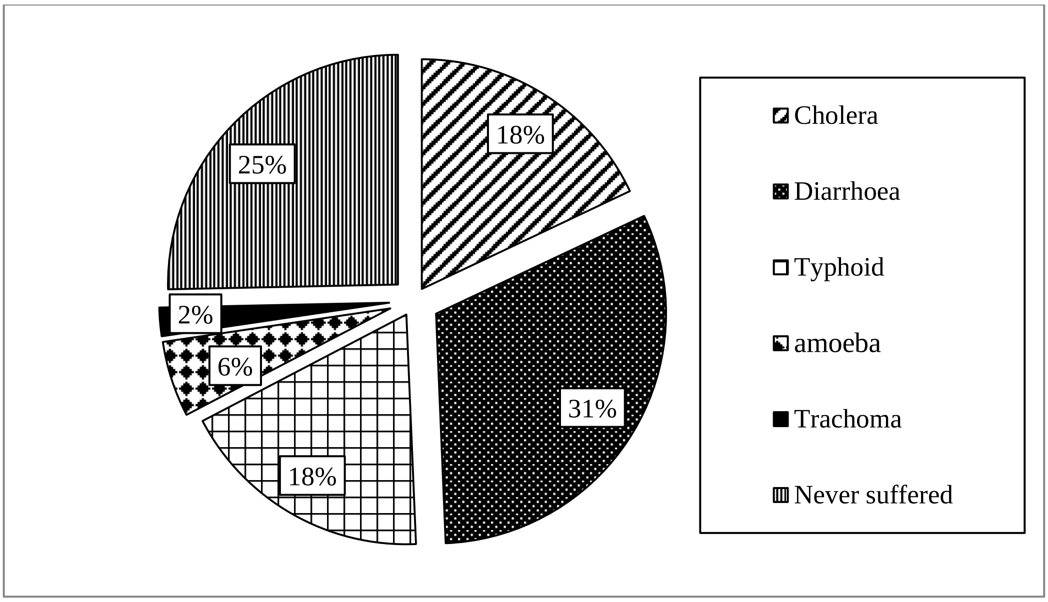


Figure 14: Cases of disease infection among households

The high incidences of waterborne diseases demonstrated among households can be attributed to appalling sanitation situation. Similar claims have been pu forward by Singh and Turkiya (2013) in their study on household sanitation and drinking water consumption patterns in rural India.

Regarding hygiene education, only 54 % of the households interviewed indicated they had received hygiene education on water handling practices and best sanitation practices. The study however found out that households that had received hygiene education had improved practice of hand washing (r=0.92). The reason could be due to the role played by hygiene education in exposing the individuals to optimal hygiene practices. Huber and Mosler (2013), demostrate too that hygiene interventions, such as health and hygiene education improved best practices such as hand-washing and significantly contribute to reduced diarrhoeal disease levels in households. In this study, majority of the households that had received education however, cited lack of reliable sources of income as a drawback of implementation. In a research to assess water and sanitation hygiene knowledge attitude practice in Urban Slum Settings India by (Joshi *et al.*, 2014), it was found that income, education level, awareness, and exposure to media are major factors that impact the individual-level decision to treat water before using it. Knowledge about waterborne diseases, exposure to water quality information campaigns, and participation in community organizations have also been found to impact drinking water treatment behaviour (Katuwal *et al.*, 2015). Studies by Behrman and Wolfe, (1987); Azage and Haile, (2015), reveal that mother's schooling affect family health, nutrition, medical care usage, and household sanitation.

4.8 Analysis of bacteriological parameters

4.8.1 Sanitary survey of drinking water sources

On-site sanitary inspection around water points was performed according to the questions proposed by the World Health Organization (1997) as given in Appendix 3. The ROC scores range from a low risk of contamination (scores = 0–30%), through a medium (40–50%) or high (60–70%) risk of contamination, to a very high risk of contamination (80–100%). The sanitary risk scores included, borehole water points (0.41), hand-dug wells (0.55), water pans (0.64) and river sources (0.82). According to the findings of the sanitary inspection, activities cited around water sources included water fetching (65%), watering animals (19%), washing (10%) and bathing activities (6%). It was noted that at some water points especially rivers and water pans, all these activities went hand in hand and this therefore implies that the water fetched could be more contaminated than at other times. Human and animal faecal matter was spotted near the rivers banks while at some points, latrine facilities were situated very close to the river banks and whenever it rained, faecal matter could easily find its way into the river. These conditions were treated as potential sources of faecal contamination of the rivers and hence were cited as a major threat to water quality. In a study conducted in peri-urban tropical lowlands of Dar es Salaam, Tanzania it was found that sanitary inspection of wells using risk-of-contamination scoring indicated a high predictive ability for bacterial faecal pollution (Mushi *et al.*, 2012).

Sanitary survey around hand dug wells revealed that 82% of the sources were unprotected. The wells had a dirty bucket and rope that were kept outside the well and dipped back in when retrieving water, providing another opportunity for contamination. At some point, the water points with lids were left uncovered after fetching water especially in hand-dug wells. Animals such as goats could be spotted climbing on top of the water slabs putting the water to contamination risks. Some of the unsanitary conditions identified around the water sources have been presented in the Table 13.

Table 13: Per-cent water sources with various unsanitary conditions

Unsanitary activities/ conditions	Percent
Bathing at water points	22%
Watering animals	43%
Washing clothes	12%
Presence of faecal matter	18%
Household waste disposal	5%
Total	**100%**

The combined analysis of sanitary inspection and water quality data can be used to identify the most important causes of and control measures for contamination (Gunnarsdottir *et al.,* 2012). Sanitary risk assessment can help to identify pathways for contamination and combining the two measures could be one way to assess safety. Research suggests that sanitary risk factors impact water quality. One study in Bangladesh, however, looked at tube well water quality contamination and found that it was not associated with a positive sanitary inspection score (Luby *et al.*, 2008). A study in Uganda of protected springs determined that some of the sanitary risk factors have a stronger association with contamination than others (Howard *et al.,* 2013).

4.8.2 Variation in mean bacterial counts

The mean colony counts on microbiological parameters in water samples were compared for the different bacterial organisms among the water sources. An analysis of variance tests revealed there was a statistically significant difference in means of counts between different bacterial organisms at $p<0.05$ for *Faecal streptococci* ($p=0.007$), *Escherichia coli* ($p=0.002$), *Salmonella typhi* ($p=0.141$) and Total coliform bacteria ($p=0.009$) among the sampled water sources. *Escheircia coli* counts were lower compared to the other bacterial organisms among the water sources. However, a comparison of the *E. coli* colony counts with the World Health Organization (WHO) guidelines for drinking water quality (Table 14) revealed the contamination levels to be high thus compromising bacterial quality of such sources.

Table 14: WHO water quality risk levels

Risk level	*E. coli* (CFU/100 mL)
Conformity	<1
Low	1–10
Intermediate	11–100
High	101–1,000
Very High	>1,000

Source: Adapted from WHO, 2004.

4.8.3 Microbial variation across different water sources

Water samples from different water sources such as boreholes, hand-dug wells, water pans and rivers were analysed for their bacteriological properties. All the bacteriological parameters sampled indicated a significant variation in their means with respect to water sources. The means for borehole sources had a significant variation with respect to sites (F= 4.327, 3.321, 7.778, 8.124 and 5.043 for *E. coli*, *Faecal streptococci*, *Salmonella typhi* and

Total coliform respectively, df= 3, 29 and P<0.05). Borehole sources however recorded relatively lower contamination levels compared to other water sources. The reason could be due to the role played by source protection. Bain *et al.* (2014) supports this finding through an explanation that efforts by communities to safeguard their water sources has played a great role in influencing microbial characteristics of water source by reducing contamination levels.

For all the hand-dug well sources, all the microbiological parameters showed significant variation with respect to sites (F= 4.958, 11.101, 2.519, 3.165 and 6.262 for *E. coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliform respectively, df= 3, 29 and P<0.05). hand-dug wells formed relied on by 52% oh the households interviewed during the research. All the river sources means were also significantly different with respect to sites, (F= 5.264, 8.315, 27.057, 2.778, and 12.041 for *E. coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliform respectively, df= 3, 29 and P<0.05). River sources recorded higher means of bacterial concentrations than all other sources. This can be explained by the various activities uniquely contributing to contamination around rivers such as the rampant defecation activities and animal watering in rivers. The findings are similar to a study by Luby *et al.*, (2008), that linked high microbial contamination to high rate of domestic activities around rivers. For all these water pan sources, means were significantly different with respect to sites, (F= 4.664, 8.145, 17.012, 3.842, and 4.561 for *E. coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliform respectively, df= 3, 29 and P<0.05). Anthropogenic activities could have been responsible for the high contamination exhibited by the waterpan sources. Similar findings have been put froward by Hennani *et al.* (2012), who sates that defecation practices around water sources contribute to high presence of faecal pathogens in water bodies. Figure 15 shows the individual mean bacterial counts for the different water sources.

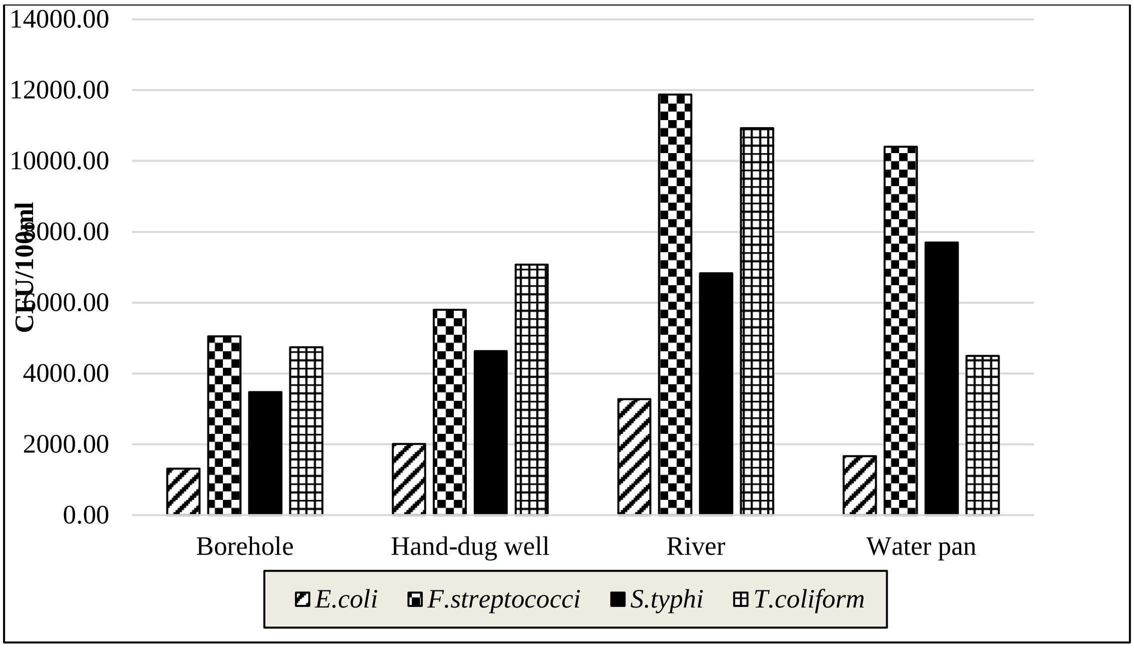


Figure 15: Mean bacterial counts per water source

4.8.4 Comparison of water quality at source and at household

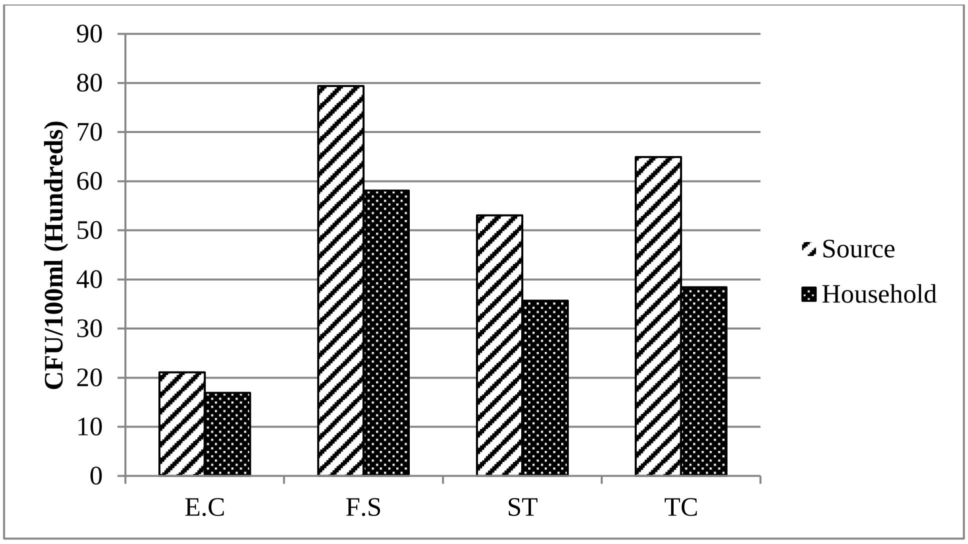
Household samples were collected from the storage vessel then being used for drinking water. The female head of household was asked to provide the sample by demonstrating how she would obtain drinking water for a child. The sample was then taken from the cup or other utensil from which the water would have been consumed. Household samples were coded and matched with the source from which they were drawn. Analysis of variance test revealed that there was a significant difference between the mean bacterial counts at household samples (F=3.739, 3.943, 6.592, 12.464 and df=3, $p<0.05$ for *E. coli, Faecal streptococci, Salmonella typhi* and Total coliform respectively). The difference in means at the household level between those using improved sources such as boreholes and those using un-improved sources was also statistically significant at the 95% confidence level (P=0.024). The mean bacteria counts recorded both at household and at source of various water points are shown in Table 15.

Table 15: Bacterial coliform counts from source and household samples

	Source	E.C	F.S	S.T	T.C
At source	*Borehole*	14.89	74.63	34.70	47.41
	Well	24.36	66.23	45.50	74.50
	River	31.47	109.8	68.25	89.25
	Water pan	13.64	66.89	63.75	48.50
Average (counts)		**21.09**	**79.38**	**53.05**	**64.92**
At Household	*Borehole*	13.09	50.52	23.74	24.53
	Well	21.51	55.20	32.17	36.54
	River	17.02	38.75	44.39	49.86
	Water pan	14.87	88.00	42.43	42.61
Average (counts)		**16.62**	**58.12**	**35.68**	**38.39**
% Av. Reduction		**21.19**	**32.75**	**32.74**	**40.87**

Legend: EC: *Escherichia coli*, FS: *Faecal streptococci*, ST: *Salmonella typhi*, TC: Total coliform

From Table 15, the results indicate higher bacterial densities recorded at the source compared to those at the household levels. This greater contamination levels at the source is traced to faecal contamination activities around these sources. As indicated in Table 15, there was a greater reduction in Total coliform (40.87%), *Salmonella typhi* (32.74%), *Faecal streptococci* and *Escherichia coli* (21.19%). The reduction underscores the importance of improved water treatment and handling practices at household. Similar findings have been put forward by (Clasen, 2015). Figure 16 shows a graphical presentation comparing the mean bacterial counts from source and household samples.



Legend: EC= *Escherichia Coli* FS= *Faecal Streptococci*, ST=*Salmonella typhi*, TC=Total Coliform

Figure 16: Mean bacterial colony counts of source and household samples

An analysis for bacterial parameters in paired samples from 15 water points revealed a higher number of *E. coli* and *Faecal streptococci* coliforms in only 4 out of 15 households (13%) analysed, at the household level than at the source. Households relying on borehole for drinking water specifically recorded a greater increase in *E. coli* and *Faecal streptococci* coliforms at household level than at the source. Although no statistical correlation could be drawn between water management practices and water quality deterioration, the survey of the study households gave an indication of the possible contributory role of their knowledge, attitudes and practices to water contamination after provision. Some of the potential water related sources of contamination were poor source protection and location, use of unimproved water source and poor knowledge and practice of household water treatment methods, poor hand washing practices in terms of percentage that wash hands and use soap. The findings are consistent with the results of a study carried in Kailahun District of Sierra Leone in which 45% of water samples collected from source was contaminated and at point-of-use, the contamination was higher at 65% (Clasen and Bastable, 2003). This indicates that water handling, storage, and hygiene at the household principally had a great impact in further determining the water quality. Hence, even if the water is safe at the source, the possibility of it being contaminated by the time it reaches the intended user is quite high. They point to the need to extend drinking water quality beyond the point of distribution to the point of consumption. The options for such extended protection, including improved collection and storage methods and household-based water treatment, are thus necessary. In particular, hygiene practices such as cleaning the container used for transportation from water collection point to household storage, cleaning of drinking vessels such as cups, glasses and mugs before it is consumed, always handling water with clean hands, point of use water treatment along with safe storage and proper handling of water could help minimise the contamination at the household (Jagals, 2006).

In general, it can be observed that water from most of the water points were contaminated with bacterial pathogens of faecal origin hence, poor quality. Most of the water samples were below the microbiological water quality standards set by the World Health Organization which require that water intended for human consumption should contain no microbiological agents that are pathogenic to humans. In particular, World Health Organisation has set a maximum allowable limit levels at 0/100ml of drinking water for *E. coli* (Refer to Table 12) and faecal coliforms (WHO, 2004). The water sources sampled hence were found unfit for drinking purposes owing to the high microbial colony concentrations observed.

4.9 Spatial distribution of open defecation points and latrine coverage

4.9.1 Latrine coverage in Burat ward

The open defecation points in both the open defecation free and open defecation prone areas of Burat ward were assessed and mapped (Figure 17). This was conducted in three wards namely; Game, Kampi Turkana and Kilimani. Kilimani ward was found to be largely open defecation free and exhibited better latine coverage compared to the neighbouring villages. In general, a remarkable coverage of sanitation was displayed in Burat Ward, which is largely ODF with latrine coverage ranging between 0-20% in ODNF villages and 20-80% in the largely ODF villages. The increase in latrine coverage in ODF villages can be attributed to the awareness created by CLTS initiatives among these villages which equips them with knowledge on best sanitation practices.

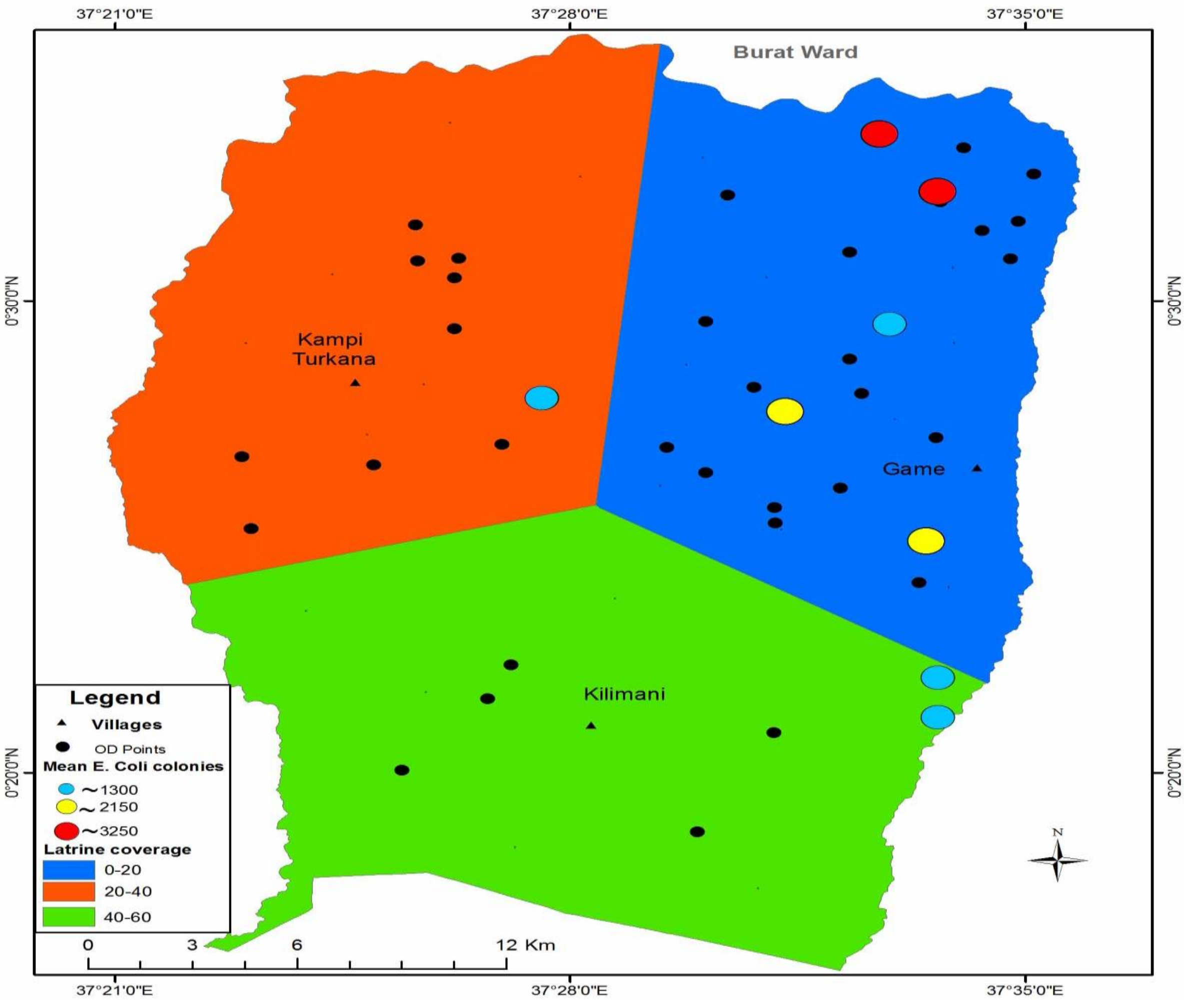


Figure 17: Spatial distribution of open defecation points in Burat Ward.

These results explain that latrine coverage is a major predictor of the sanitation conditions of an area. Similar claims have been put forward in a study by Murugesan *et al.,*

(2008) who demonstrated the need to embrace use of toilets and latrines in order to eliminate open defecation practice. Tambekar and Neware, (2012), indicates that open defecation was one of the most important factors for polluting the ground water sources such as open well, hand pumps, and tube well in villages and better sanitation not only improves human health but also promotes economic and social development.

4.9.2 Latrine coverage in Ngare Mara ward

Ngare Mara ward however, was marked with reduced sanitation levels with the ODNF villages recording latrine coverage of between 10-30%, while the ODF villages had latrine coverage of up to 70% (Figure 18). In general a relationship between latrine latrine coverage and the practice of open defecation was exhibited in the two wards. Consequently, villages with lower latrine coverage were characterized by higher rates of open defecation than those with higher latrine coverage. Latrine coverage has been shown to determine the spatial distribution of open defecation (Coffey *et al.*, 2014). Also, the presence of latrines has been demonstrated to promote better faecal disposal practices (Moruff, 2012).

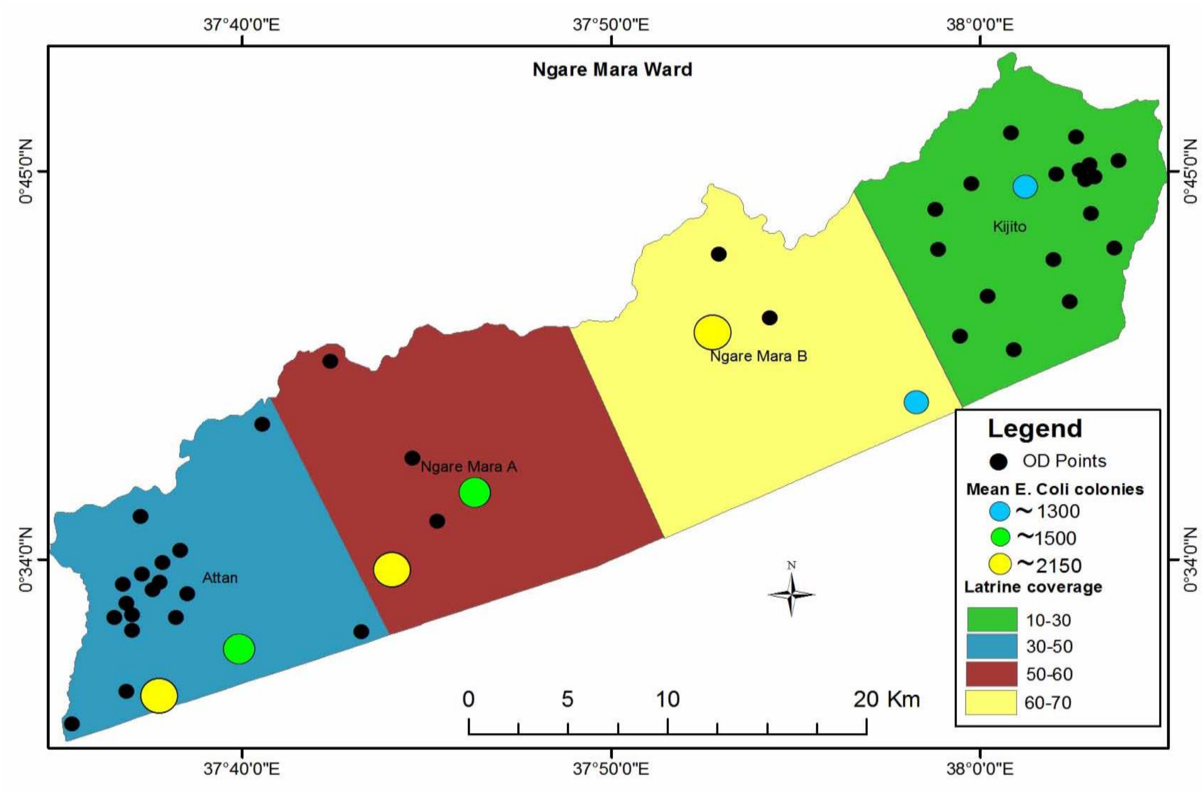


Figure 18: Spatial distribution of open defecation points in Ngare Mara Ward.

The spatial distribution of *E. coli* bacterial counts were also recorded for the various water sources between the open defecation free and open defecation not areas of Burat ward

(Figure 17) and Ngare Mara ward (Figure 18). Areas with lower latrine coverage and consequently higher open defecation rates exhibited higher contamination with *E. coli* pathogens. This underscores that open defecation plays a great role in determining contamination of water sources from various bacterial pathogens. This is because open defecation introduces bacterial pathogens into the environment which finally end up in water bodies. A study conducted to analyze the effect of open defecation practices on chemical and bacteriological quality of water in Amravati district also revealed a higher contamination in ODNF villages than ODF villages with thermo-tolerant *E. coli* (Tambekar and Neware, 2012). UNICEF (2008) puts the open defecation coverage in Isiolo County to be at 48%. This indicates a positive development in terms of eradicating open defection practice in Isiolo County.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the findings of the study, the following conclusions were drawn:

1. Generally, poor faecal disposal habits occasioned by low latrine presence was recorded in open defecation not free (ODNF) villages when compared to open defecation free ODF villages depicting the varying degrees of sanitation.
2. The majority of residents of Isiolo County rely on un-protected water sources such as hand-dug shallow wells, water pans and stream sources for their drinking water source. The sanitary risk survey conducted around water source revealed high risk score for rivers (0.84) and hand-dug wells (0.64), water pan (0.55) and slightly lower risk score for borehole sources (0.41). Such unsanitary conditions posed a risk to human health of those relying on the water sources for drinking purposes.
3. The water treatment methods by residents included boiling (6%), chemical (18%) and leaving to settle (20%), while the remaining (53%) did not employ any treatment. These results indicate that less costly and less time consuming options for drinking water treatment were preferred as compared to the rigorous but rather safer options.
4. Generally, higher contamination levels of *E. coli*, *Faecal streptococci*, *Salmonella typhi* and Total coliforms were measured in source samples than household stored water. However, all the drinking water samples failed to meet the recommended WHO levels of 0/100 ml coliforms for drinking water quality.
5. Latrine coverage within the villages had an influence on the spatial distribution of open defecation points. This was demonstrated by the high incidences of open defecation in villages with low latrine coverage.

5.2 Recommendations

Based on the findings of the study, the following recommendations have been made;

1. There is need to increase the proportion of households having access to latrine facilities. Through the community led total sanitation (CLTS) awareness approach. This will enhance the number of villages that are open defecation free.
2. There is need to increase access to improved water sources especially for sources used by residents for drinking purposes in order to reduce the likelihood of faecal contamination of these sources. Un-sanitary activities around water points should also

be monitored and adequate corrective measures such as source protection taken so as to prevent further contamination.

3. There is need for households to safeguard drinking water quality, through practising proper treatment and safe storage at households. The goal of this is to maintain the drinking water quality to the WHO acceptable microbiological standards so as to realise health benefits.
4. Improving drinking water quality is a modest step towards improving overall health for human beings. As such, there is the need to focus more on methods of point of use treatment of drinking water by creating awareness on use of such best practices. This will lead to improved water quality as advocated for by the SDG's (Goal 6).
5. Increasing the number of households with access to latrine facilities will lead to adoption of better faecal disposal. Further, there in need to create awareness on the importance of latrine use among such households. This will not only ensure a clean environment but also help in safeguarding quality of water sources hence improved aspects of human health as espoused in the Sustainable Developemnt Goals 3 and 6.

Recommendations for future research

The study focussed on one point analysis of microbiological parameters presence in drinking water sources. The study therefore did not take into account the disparity in bacteriological quality of these water sources occasioned by seasonal variations which often significantly determine the microbial densities in the water sources. As a recommendation for future research, there is need to conduct a study that will assess variations in faecal contamination of drinking water sources at different climatological seasons. In terms of sanitation, a future study to assess the contribution of population density on overall faecal contamination of water sources is suggested.

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APPENDICES

Appendix 1: Membrane filtration techinque (APHA, 2005)

Analysis for *E. coli*, *faecal streptococci, total coliform* and *Salmonella typhi*

Laboratory apparatus/ materials

i) Water sample
ii) 47-mm Petri plates
iii) Sterile membrane filter apparatus
iv) Sterile 0.45-μm filters (2)
v) Blunt-tip forceps
vi) Alcohol
vii) Sterile pipette or graduated cylinder
viii) Sterile rinse water
ix) Colony counter

Procedure

1) Set up the filtration equipment. Remove wrappers as each piece is fitted into place.

    a. Attach the filter trap to the vacuum source.

    b. Place the filter holder base (with stopper) on the filtering flask. Attach the flask to the filter trap. *Disinfect the forceps by dipping in alcohol and burning off the alcohol. Keep the beaker of alcohol away from the flame.*

    c. Using the sterile forceps, place a filter on the filter holder.

    d. Set the funnel on the filter holder, and fasten it in place. Filter the sample.

2) Filter the sample.

    a. Shake the water sample well to re-suspend all material, and pour or pipette a measured volume into the funnel. *(For samples of 10 ml or less, pour 20 ml of sterile water into the funnel first.)*

    b. Turn on the vacuum, and allow the sample to pass into the filtering flask. Leave the vacuum on.

    c. Pour sterile rinse water into the funnel. Rotate the funnel while pouring to wash bacteria from the sides of the funnel. *(Use the same volume as the sample.)* Allow the rinse water to go through the filter. Turn the vacuum off.

3) Inoculate the filter

   a. Carefully remove the filter from the filter holder using sterile forceps.

   b. Carefully place the filter on the Agar. Do not bend the filter; place one edge down first, then carefully set the remainder down. Do not leave air spaces between the filter and agar. Place the filter on the agar as it was in the filter holder.

4) Invert the plate and incubate it for 24 hours at 37°C for *E. coli* using *Chromocult agar*; at 37°C for 24 hours for *Total coliform* using *Chromocult agar*, at 18°C for 18-24hours for *Faecal streptococci* using *CLED media* and at 35°C for 24-48 hours for *Salmonella typhi* using *SS Agar*.
5) Examine for colony growth at the end of the culturing period and place under a colony counter to begin counting. Count plates with 20 to 80 coliform colonies, and not more than 200 colonies of all types.
6) *E. coli* will form bluish colonies, *Total coliform*s will form pink-red colonies, *Faecal streptococci* will form yellow colonies while *Salmonella typhi* will form pink colonies with dark spots. Calculate the bacteria in the original water sample:

Calculation of coliform density

$$\text{Number of coliforms (per 100 ml of water)} = \frac{\text{Number of coliform colonies x 100}}{\text{Volume of water filtered}}$$

Appendix 2: Household questionnaire

Dear Respondent,

My name is Joab Okullo, a student pursuing an MSc. in Environmental and Occupational Health at Egerton University. Currently, I am conducting research on Water, Sanitation and Hygiene issues in Isiolo County. I will highly appreciate your contribution through answering the following questions.

A: SOCIO- DEMOGRAPHIC INFORMATION

1. Name of Respondent (Optional)……………………………………
2. Sex: Male [ ] Female [ ]
3. Age of Respondent ………………………………………………….
4. What is the household size? ………………………………………...
5. Village/ Ward…………………………………………………………
6. Highest level of education of the household head?

   i) No formal education [ ] ii) Primary [ ] iii) Secondary [ ] iv) Tertiary [ ]

7. What is your main source of household income? …………………………………...
   i. Farming [ ]
   ii. Livestock keepers [ ]
   iii. Casual employment [ ]
   iv. Artisan/ Juakali [ ]
   v. Salaried employment [ ]
   vi. Trading [ ]
   vii. Others(Specify) [ ]

B: WATER ACCESS AND USE

8. What is the MAIN source of drinking water in your household?
   i. Piped water in dwelling [ ]
   ii. Borehole [ ]
   iii. Rainwater tank on site [ ]
   iv. Public/communal tap/water kiosk [ ]
   v. Hand dug wells [ ]
   vi. Mobile water bowser/ vendors [ ]
   vii. River/stream, wells and springs [ ]
   viii. Water pans/ earth dams/ponds [ ]

ix. Other (specify) ……………… [ ]

9. How far is the source of your drinking water from household?

i. Less than 500m [ ]

ii. 500m-1km [ ]

iii. 1km- 2kms [ ]

iv. 2-5kms [ ]

v. Over 5kms [ ]

10. What is the average time you take to access the water source?

i) Less than 30mins [ ] ii) 30mins-1hr [ ] iii) 1-2hrs [ ] iv) More than 2hrs [ ]

11. What is the average water quantity (Litres) used in the household on a daily basis?

i) 0-20 [ ] ii) 20-40 [ ] iii) 40-60 [ ] iv) 60-80 [ ] v) Above 80 [ ]

12. Who fetches drinking water MOST times in the household?

i. Children [ ] ii. Mother [ ] iii. Vendors [ ] iv. House maids [ ] v. Father [ ]

vi. No specific individual [ ]

13. What time of day do you mostly withdraw the water from source?

i. Morning [ ] ii. Daytime [ ] iii. Evening [ ] iv. No specific time [ ]

14. Why the indicated time?

i. Hot weather [ ]

ii. Water cleaner at this time [ ]

iii. Water opened at this time [ ]

iv. In order to engage in other HH chores [ ]

v. whenever need arises [ ]

15. What activities Mostly take place at time of fetching household water?

i. Washing [ ] ii. Bathing [ ] iii. Watering animals [ ] iv. Water fetching [ ]

v. Others (Specify) [ ]

C: WATER TREATMENT AND HANDLING

16. Do you treat your drinking water? i. Yes [ ] ii. No [ ]

17. If Yes, what method do you use?

i. Boiling [ ]

ii. Chemical [ ]

iii. Solar disinfection [ ]

iv. Filtering [ ]

iv. Others (Specify) [ ]

18. Why do you prefer the method indicated above?

i. Cheap [ ]

ii. Efficient [ ]

iii. Safe [ ]

iv. Other (Specify) [ ]

19. If NOT, why don't you treat your water for drinking?

i. Can't afford [ ]

ii. Health reasons [ ]

iii. Cultural reasons [ ]

iv. Don't see the need [ ]

v. Consider water safe [ ]

20. What criteria do you use to determine safe water?

i) Colour [ ] ii) Taste [ ] iii) Smell [ ] iv) Suspended solids [ ] iv) Source [ ]

v) Others (specify)........................

21. What type of container do you prefer for storage of drinking water?

i) Pot [ ] ii) Bucket [ ] iii) Bottle [ ] iv) Jerrican [ ] v) Other (Specify).................

22. Why prefer the container type mentioned above?

i)Ease of withdrawal [ ] ii) Easy to clean [ ] iii) Affordable [ ] iv) Safety reasons [ ]

23. Is container used for storage same or different as that for fetching?

i. Yes [ ] ii. No [ ]

24. How often do you clean your drinking water storage container?

i. Once a week [ ]

ii. Twice a week [ ]

iii. Thrice a week [ ]

iv. Once a month [ ]

v. Whenever container is empty [ ]

vi. Daily [ ]

v. Never [ ]

25. Is drinking water vessel normally covered? i.Yes [ ] ii. No [ ]

26. If yes, what do you use for covering the water?

i. Plate [ ]

ii. Clothing [ ]

iii. Container Lid [ ]

iv. No covering [ ]

27. Where in the house is the drinking water container located?

i. Living room [ ]   ii. Bedroom [ ]   iii. Kitchen [ ]   iv. Dinning [ ]

28. Are hands washed before accessing the water source? i. Yes [ ]   ii. No [ ]

29. Is the mouth of the water storage container   i. Narrow [ ]   ii. Wide [ ]

30. How do you obtain the water from the storage container?

i. Dipping [ ]   ii. Pouring [ ]   iii. Spigot [ ]

31. Do you consider the water you use to be safe for drinking purposes? i. Yes [ ] ii. No [ ]

If not, why?

i. Bad taste [ ]

ii. Turbid [ ]

iii. Has odour [ ]

iv. Has dirt [ ]

v. Others (Specify) [ ]

D: SANITATION AND FAECAL DISPOSAL

32. Does the household have a sanitation facility? Yes [ ] No [ ]

33. If yes, what type of sanitation facilities is present in the household?

i. Pit latrine [ ]
ii. VIP latrine [ ]
iii. ECOSAN toilets [ ]
iv. Bucket system [ ]
v. Flash connected to septic tank [ ]
vi. Other (specify) …………………..[ ]

34. What is the mode of the sanitation facility

i) Private [ ]   ii. Shared [ ]   iii. Public toilet [ ]   iv. Open defecation [ ]

35. What is the current condition of the sanitation facility used by the household?

i) Overflow/full [ ] ii) Dirty/smelly [ ] iii) Structure dilapidated [ ] iv) Inadequate size [ ]

v) Sound state [ ] vi) Unstable/collapsed [ ]

36. If No sanitation facility present in household, where do adults relieve themselves?

i. Use neighbor’s latrine [ ]

ii. Bush disposal [ ]

iii. Dig hole for immediate use [ ]

iv). Engage in open defecation [ ]

37. How do you dispose child faeces?

i. Burry [ ]

ii. Dispose in the open to dry [ ]

iii. Toilet disposal [ ]

iv. Bush disposal [ ]

v. Other (specify) [ ]

38. If NO latrine in household, give reason?

i. Cost of construction is high [ ]

ii. Don't see the need to have one [ ]

iii. No response [ ]

iv. Migrated here recently [ ]

v. Poor soil formation/ collapse [ ]

vi. Not provided by the landlord [ ]

vii. Other (specify) [ ]

39. What is the location of sanitation facilities with respect to household/ water sources?

i) Within 10m [ ] ii) 10-30 m [ ] iii) 30- 50m [ ] iv) Beyond 50m [ ]

40. What challenges do you face with regard to faecal disposal?

……………………………………………………………………………………………….

E: WATER BORNE DISEASES

41. Has any of your family members suffered from any water-borne diseases?

i. Yes [ ] ii. No [ ]

42. If YES, which diseases?

i. Cholera [ ] ii. Diarrhoea [ ] iii. Dysentery [ ] iv. Typhoid [ ]

v. Amoeba [ ] vi. Others (Specify) [ ]

43. What do you think was the suspected cause of the disease?

....

THANK YOU FOR YOUR CONTRIBUTION

Appendix 3: Sanitary surveys form

A: Sub-surface and underground sources (Boreholes, wells)

I Type of facility: Specify ………………………………………..

1. General information: Village...

2. Name of water source …………………………….....................

3. Date and time of visit..

II Specific diagnostic information for assessment	**Risk**
1. Is there a latrine/ faecal disposal point within 10 m of the water point?	Y [ ] N [ ]
2. Is the nearest latrine / faecal disposal point on higher ground than the water point?	Y [ ] N [ ]
3. Is there any other source of pollution (e.g. animal excreta, rubbish) within 10 m of the water point?	Y [ ] N [ ]
4. Is the drainage poor, causing stagnant water within 2m of the source?	Y [ ] N [ ]
5. Is there a faulty drainage channel? Is it broken, permitting ponding into the water source?	Y [ ] N [ ]
7. Is the concrete floor less than 1m wide around the water point?	Y [ ] N [ ]
8. Are the walls of the well inadequately sealed at any point for 3m below ground?	Y [ ] N [ ]
9. Are there any cracks in the concrete floor around the source which could permit water to enter the well?	Y [ ] N [ ]
10. Are the rope and bucket left in such a position that they may become contaminated? (For wells and boreholes)	Y [ ] N [ ]
11. Does the installation require fencing?	Y [ ] N [ ]

Total score of risks .... /11

Contamination risk score: 9–11 =very high; 6–8 = high; 3–5 =intermediate; 0–2 =low

B: surface source and abstraction (River/ stream sources and water pans)

I Type of facility: Specify …………………………………………..

1. General information: Village...

2. Name of water source ……………………………….....................

3. Date and time of visit...

II Specific diagnostic information for assessment	Risk
1. Is there any human habitation upstream, polluting the source?	Y [ ] N [ ]
2. Are there any evidence of open defecation close to the watering points along the stream?	Y [ ] N [ ]
3. Is there other evidence of unsanitary conditions along the river/ stream?	Y [ ] N [ ]
4. Is the watering of animals taking place within 10m of the river/ stream?	Y [ ] N [ ]
5. Is there human practices such as washing, cleaning and bathing activities taking place inside the river/ stream?	Y [ ] N [ ]
6. Is there water fetching for drinking taking place at same point used for washing and bathing in the river?	Y [ ] N [ ]
7. Is there evidence of latrines uphill or near the river/ stream banks?	Y [ ] N [ ]
8. Is there evidence of run-off water washed directly into the river during the rainy seasons?	Y [ ] N [ ]
9. Is the area around the water source fenced?	Y [ ] N [ ]

Total score of risks.................... /10

Contamination risk score: 9–10 = very high; 6–8 = high; 3–5 =intermediate; 0–2 =low

Appendix 4: Observation checklist

1. Are sanitation facilities present within the particular household?
2. What are the types of sanitation facilities present at the household (if any)?
3. Hygiene conditions of sanitation facilities available to the household? Observe their state.
4. What is the location of sanitation facilities with respect to household/ water sources?
5. Is there evidence of faecal matter within the vicinity of the household?
6. Are there any unhygienic conditions observed within the household?
7. Observe for non-conformities in water handling and storage at household.

The following important notes were noted;

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Appendix 5: Key informant schedule

Name……………………………………………..

Designation………………………………………

Date of visit………………………………………

1. What are the general socio-cultural beliefs of residents towards open defecation?
2. What is the general latrine coverage of the study areas?
3. Are there faecal-oral related diseases affecting residents? Name them.
4. What is the burden of open defecation in Isiolo County?
5. What is the proportion of the population without access to clean and potable water?
6. What opportunities are there for improvement in water and sanitation?

Appendix 6: NACOSTI Research Authorization

NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION

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When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O.Box 30623-00100
NAIROBI-KENYA

Ref No. **NACOSTI/P/17/71277/16237**

Date: **3rd April, 2017**

Joab Odhiambo Okullo
Egerton University
P.O.Box536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Assessment of contribution of faecal disposal practices on the bacteriological quality of drinking water sources in Isiolo County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Isiolo County** for the period ending **3rd April, 2018.**

You are advised to report to **the County Commissioner, the County Director of Health Services and the County Director of Education, Isiolo County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

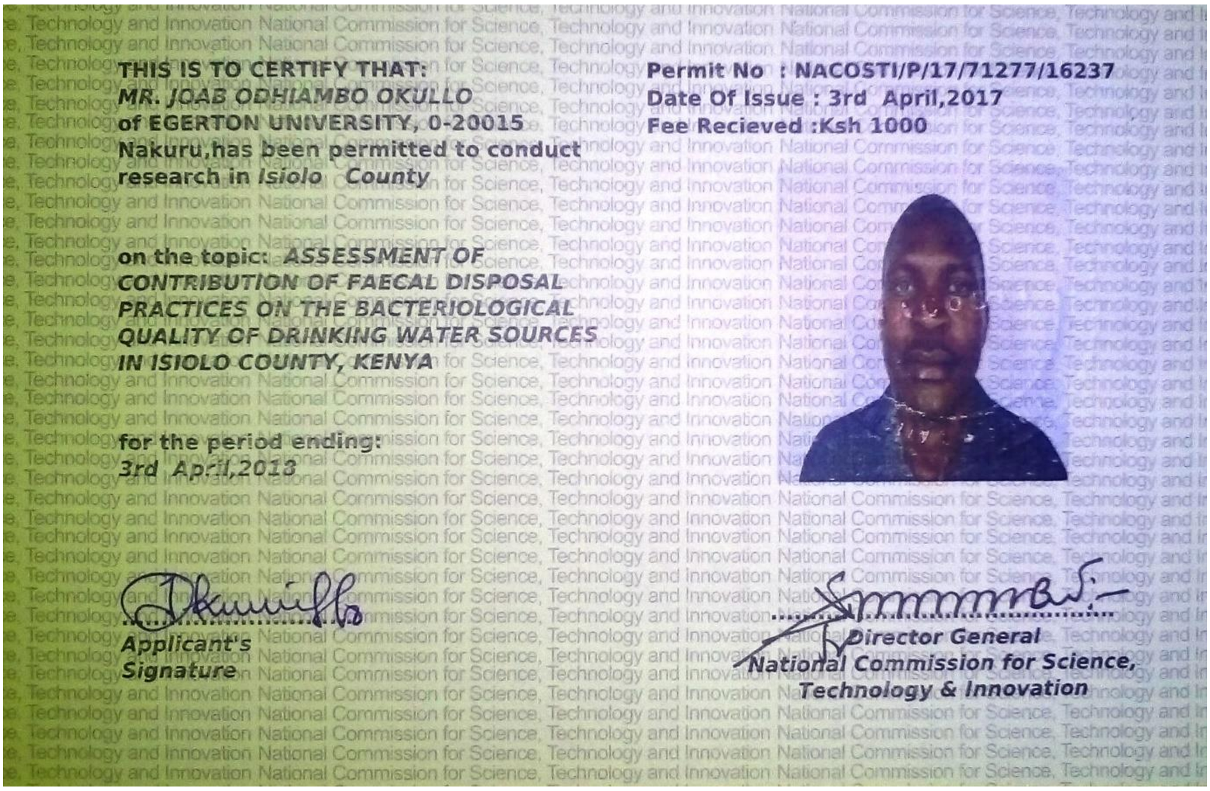
Copy to:

The County Commissioner
Isiolo County.

The County Director of Health Services
Isiolo County.

National Commission for Science, Technology and Innovation is ISO9001: 2008 Certified

Appendix 7: NACOSTI Research Clearance Permit



THIS IS TO CERTIFY THAT:
MR. JOAB ODHIAMBO OKULLO
of EGERTON UNIVERSITY, 0-20015
Nakuru,has been permitted to conduct
research in *Isiolo County*

on the topic: *ASSESSMENT OF CONTRIBUTION OF FAECAL DISPOSAL PRACTICES ON THE BACTERIOLOGICAL QUALITY OF DRINKING WATER SOURCES IN ISIOLO COUNTY, KENYA*

for the period ending:
3rd April,2018

Permit No : NACOSTI/P/17/71277/16237
Date Of Issue : 3rd April,2017
Fee Recieved :Ksh 1000

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation