MICROBIOLOGICAL WATER QUALITY OF WATER PANS IN RELATION TO PREVALENCE OF WATER RELATED DISEASES IN CENTRAL AND SOUTH BARINGO, 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

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted or presented for examination in any other institution either in part or as a whole.

Signature: ……………... Date: ……………………………

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Recommendation

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DEDICATION

I dedicate this work to my beloved parents (Mr and Mrs Symon Koech), siblings (Christine Jebichii, Mariana Jeptoo, Emmanuel Kipkorir, Naomy Jepkogei, Noah Kiprop and Rose Jerono) who gave me moral and financial support during the study period. My loving husband Frank Kipkoech and our daughter Victoria Jebet for motivation and humble time during the writing of the thesis.

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ABSTRACT

Water pans are excavated earth with embankments used as boundaries that are used to harvest surface runoff. Water pans are the main sources of water for domestic purposes in arid and semi-arid lands, however, lack of protection and water treatment of this water sources exposes the dependent communities to human health problems. This study sought to assess the microbiological water quality of water pans in relation to prevalent water-related diseases in the study area. This was achieved through conducting a cross-sectional survey on the household sanitation and water handling practices, and a sanitary survey to assess the state of water pans in terms of their exposure to microbial contaminants. Further, microbial water analysis using Membrane Filtration Technique (MFT) were performed on water collected from protected and unprotected water pans. Data analysed using descriptive and inferential statistics. The results indicated that water pans were contaminated by animal and human waste through runoff from the adjacent lands where grazing and open defecation occurred. There was no statistically significant spatial variation in several microbiological parameters between the protected and unprotected water pans ($p>0.05$) during the dry season. However, T-test indicated a significant difference in *Escherichia coli* (df=5,t=-4.37, p=0.012), *Fecal streptococcus* (df=5, t=-3.68, p=0.021) and *Salmonella species* (df=5,t =-3.96, p=0.017) between the protected and unprotected water pans during the wet season. The household water handling practices observed in the households were inadequate as per WHO guidelines, and thus the high prevalence of water related diseases (diarrhoea (12.2%), typhoid (11%) and skin infections (19%)) within the study area. In conclusion, domestic water pans in Central and South Baringo were contaminated above the WHO drinking water quality guidelines. Given the prevalence of the selected water related diseases causing pathogens in water above the WHO drinking water quality guidelines, households are advised to treat the water before use. Further, we recommend protection of water pans from humans and animals so as to reduce contamination through animal and human waste.

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LIST OF ABBREVIATIONS

AEZ IV	Agro- ecological zone IV
AEZ V	Agro-ecological Zone V
ANOVA	Analysis of Variance
APHA	American Public Health Association
ASALs	Arid and Semi-Arid Lands
CDC	Centre of Disease Control
GPS	Global Positioning System
ICRAF	International Centre for Research in Agro forestry
KNBS	Kenya National Bureau of Statistics
MDG	Millennium Development Goals
NEMA	National Environmental Management Authority.
NDMA	National Disaster Management Authority
SID	Society for International Development
TCs	Total Coliforms
UN	United Nations
UNEP	United Nations Environmental Programme
UNICEF	United Nations Children's Fund
UNDP	United Nations Development Programme
WRMA	Water Resource Management Authority
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information.

Access to quality water is essential to health, a basic human right and a component of effective policy for health. Safe drinking water is essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all. Safe drinking water, as defined by World Health Organization guidelines, does not represent any significant risk to health over time of consumption (WHO/UNICEF, 2008; WHO, 2011). Water is a basic requirement in life. When contaminated, water can transmit diseases to a large proportion of human population within a short time span causing water related diseases.

Water related diseases are defined as any significant adverse effects on human health caused directly or indirectly by the changes in the quantity or quality of any waters. Water related diseases result due to the use of water contaminated with micro-organisms and parasites. The main sources of these pathogens in natural waters include; storm water run-off, agricultural pollution and municipal sewage (Grabow, 1996; WHO, 2008). Worldwide water related diseases claim over twelve million deaths a year. In Sub-Saharan Africa alone, there are more than two thousand children's (adults not included) lives lost every day from water related diseases (WHO/UNICEF, 2005).This is due to poor sanitation facilities, unsafe drinking, washing and cooking water. On average one tenth of each person's productive time is wasted as a result of water related disease (WHO, 2008).

Inadequate water supplies in developing countries have led to the great burden of water related diseases. Kenya is one of those countries that have been classified by the United Nations as chronically "water scarce." Due to continued population growth, it has been estimated that by the year 2025, Kenya's per capita water availability will be 235 cubic meters per year, about two -thirds less than the current 6500cubic meters (UNEP, 2010a). The Kenya water crisis is critical with the country facing the struggle to supply clean water to its population. Fifteen million Kenyans lack access to improved water supply and nineteen million Kenyans lack access to improved sanitation (World Bank, 2012). This worrying scenario have led to the occurrences of water related diseases which account for approximately 70% -80% of health issues in the Country (USAID, 2013).

Baringo County is situated in the water scarce arid and semi-arid lands (ASALs) of Kenya. Central and South Baringo are located mainly in agro ecological zone IV and V. It is made up of Mogotio, Eldama Ravine and Marigat sub-counties of Baringo County. These lands experience erratic rainfall with an annual average rainfall ranging from

150mm - 450mm in Marigat sub-county and 500mm- 800mm in Eldama/Ravine and Mogotio sub-counties, respectively (UNDP, 2013).The per capita water consumption in arid and semi-arid lands ranges between 5 and 100litres for an individual, much below the national per capita consumption of water of 200litres per person per day (Perry, 2010).

It is estimated that on average sixteen million hours are lost each year by women and girls to collecting drinking water (WHO/UNICEF, 2012).This scenario has led to low attendance ratio of females to schools in Baringo County. Water scarcity has been highlighted as the contributing factor to low attendance or absenteeism from school. In Baringo County, only 33% of female students attend school with water scarcity topping the list of factors that account for non-attendance and high drop-out rates among females (CRECO, 2012;CEDGG, 2013).

The National Drought Management Authority (NDMA) January (2014) bulletin on drought monitoring; reported that, water sources currently in use in Baringo County include water pans, dams, natural rivers, traditional river wells, springs, boreholes and lakes. Wetangula *et al.*, (2010) reports that surface water sources such as dams and water pans have been developed in Baringo County to provide water for domestic use and livestock watering. A report on water and sanitation, in Kenyan counties revealed that 29.3%, 3.4% and 2.0% of the human population in Mogotio, Eldama ravine and Marigat sub-counties respectively were using pond and dams for their domestic water uses (KNBS & SID, 2013).

However, these water sources are categorized as unimproved (WHO, 2008). Protected water pans are those water pans that are fenced off to prevent both humans and livestock from stepping into the water, whereas, unprotected water pan have no fence and there is free access to the water by both humans and livestock making them susceptible to microbial contamination. Lack of water pan protection increases the rate of water pan contamination by both human and animal faecal matter. Fecal contaminated water harbours pathogenic organisms in water that are the agents of disease transmission to human beings. A study in Abottabad revealed that drinking water in rural communities was found to be contaminated with *Escherichia coli, Salmonella* and *Clostridium* species (Jabeen *et al.*, 2013). These pathogenic organisms are responsible for the occurrences of water related diseases.

An environmental baseline survey conducted in Arus-Bogoria for geothermal development found the prevalence of water related diseases (Malaria and Diarrhoea) to be higher in Central and South Baringo (Wetangula *et al.*, 2010). Their findings concurred with the Baringo health survey report, where the prevalence of water related diseases (17%) were high in Baringo County as compared to the national prevalence rates of 15% (Ministry of Health, 2012). However, these findings associated the prevalence of water related diseases(malaria and diarrhoea) to low latrine coverage, inadequate water supply and poor housing within the study area, however it failed to highlight the relationship of the water related diseases to microbiological water quality of water pans that the local population within the study area use. Water and sanitation conditions in the rural communities of Central and South Baringo remain worse as a result of scarce safe drinking water facilities.

Central and South Baringo faces the problem of area residents sharing untreated water with domestic and wild animals. This exposes them to great risks of water related diseases. Inadequate data on microbiological water quality of water pans formed the thrust of this study. Therefore, this study sought to assess the microbiological water quality of the water pans in relation to the prevalence of water related diseases in Central and South Baringo, Kenya.

1.2 Statement of the problem

The need to respond to water scarcity scenario experienced in arid and semi-arid lands of Central and South Baringo, the national and the county governments have been excavating several water pans in the area. Reports show that, the prevalence of water related diseases in Central and South Baringo stands at 17% against the national rates of 15%. However, there is limited studies that has attempted to establish the relationship between the uses of water pan water for cooking and drinking to the high prevalence rates of the water related diseases, thus the need for this study. The aim of this study was to assess the microbiological water quality of water pans in relation to the prevalence of water related diseases in Central and South Baringo.

1.3 Objectives

1.3.1 Broad objective.

To assess the microbiological water quality of water pans in Central and South Baringo in relation to the prevalence of water related diseases so as to safeguard human health.

1.3.2 Specific objectives

1. To map and describe the location of water pans in the study area.
2. To assess the sources of microbial contamination of water pans.
3. To assess the spatial-temporal variation of Total coliform, *Escherichia coli*, *Fecal streptococci* and *Salmonella species* of water pans.

4. To assess household knowledge, attitude and water handling practices and determine how they affect drinking water quality.
5. To assess the prevalence rates of water related diseases and their distribution in relation to household water quality.

1.4 Research Questions

1. Where are the locations of water pans in the study area?
2. What are the sources of microbial contamination of the water pans?
3. What are the spatial and temporal variations of Total coliform, *Escherichia coli*, *Fecal streptococci* and *Salmonella species* of water pans?
4. What are the household's knowledge, attitudes and handling practices on drinking water in the study area?
5. What are the prevalence rates of water related diseases in the study area?

1.5 Justification

Water related diseases represent a major burden on human health worldwide. World Health Organization estimates more than four billion people suffer from diarrhea annually. Around 1.3 million deaths occur annually in Kenya due to unsafe water consumption and poor sanitation (WHO/UNICEF, 2012). This is a result of water scarcity experienced in the country. Arid and semi-arid lands remain the most affected areas in terms of inadequacy to water accessibility. This has resulted to wide use of unimproved water sources regardless of its quality before use, the case of the Central and South Baringo. This study assessed the microbiological water quality in relation to the prevalence of water related diseases. This study was in line with the United Nations Sustainable Development Goal 6.1 and 6.2 whose indicators will be proportion of people using safely managed drinking water sources and proportion of population using safely managed sanitation services including a hand washing facility with soap and water respectively. This study is consistent with vision 2030, the social pillar on water and sanitation target that aims at ensuring improved water sources in both rural and urban areas. The social pillar on the environment aims at reducing by half all the environment-related diseases. Data from this study will be beneficial to the ministry of health, community members and other stakeholders in the planning of strategies aimed at addressing water scarcity and water quality concerns and thus improve human and environmental health in the County. The data will also be beneficial in reducing water related diseases, in Central and South Baringo and other similar arid and semi-arid lands (ASALs) areas in the country.

1.6 Scope of the study

The study was limited to protected (Cheraik) and unprotected (Kapchelukuny, Kures, Chepnyorgin, Kaptipsegem and Kinyach) water pans in agro-ecological zone IV and V of the geographical Central and South Baringo (Eldama Ravine, Mogotio and Marigat sub-counties). Health centres located in agro ecological zone IV (Mogotio and Emining) and agro ecological zone V (Marigat and Kimalel). The water pan users over 18 years old were interviewed. The study was conducted between November, 2014 and October, 2015, during the wet seasons of June to July and the dry seasons of September to October, respectively. Microbial water quality assessment was limited to total coliforms, *Escherichia coli*, *Feacal streptococcus* and *Salmonella species.* The selected microorganism species are indicator organisms for feacal pollution in water sources. Water related diseases were limited to diarrhoea, typhoid and skin infections diseases.

1.7 Limitations and Assumptions of the study

However, the study was limited to:

- Phenotypic characterization of the microbial pathogens, therefore the specific infective strains present in the study area was not assayed.

This study assumed that:

- The water pans in the study area were used by the whole population.
- Respondents were able to recall and answer information correctly.
- Not all data retrieved from the health centers on water related diseases could be linked to consumption of the water pan water.
- Cultural practices of the study population did not change during the study period.

1.8 Definition of terms

The definitions given below are intended to prevent misunderstanding of the subjects used for discussion in this thesis, because not all authors attach the same meaning to the terms.

Agro-ecological zones: Geographical areas exhibiting similar climatic conditions that determine their ability to support rained agriculture.

Improved water sources: Water pans fenced and provided with distinct water points for livestock and human beings reducing microbial contamination.

Unimproved water sources: Water pans not fenced, are freely accessible by livestock and human beings, therefore increasing the rate of microbial contamination.

Microbiological water quality: Refers to the acceptability of water for household use regarding the presence or absence of the indicator organisms including Total coliforms, *Escherichia coli*, *Fecal streptococcus* and *Salmonella species.*

Prevalence: Is the measure of the number of people who have a disease at a given time in an area.

Protected water pan: A water pan fenced to prevent free access of human beings and animals to water, has a distinct water points for human and livestock to prevent microbial contamination at source.

Unprotected water pan: A water pan that has not been fenced, thus free access by human and livestock causing microbial contamination.

Water related diseases: Are all diseases or illnesses resulting from the use of contaminated water for human consumption. They are categorized into four namely; water borne, water based, water washed and water vector insect diseases.

Water borne diseases: Are diseases that occur as a result of ingesting fecally contaminated water.

Water based diseases: These are diseases that occur as a result of an individual coming in contact with water that contains the disease causing organisms, for example, the snail, therefore causing the transmission of the *Schistosome* parasites to the human body causing Bilharzia.

Water vector insect related diseases: Are diseases spread by insects that spent part of their lifetimes in water, for example, mosquitoes, causing malaria.

Water washed diseases: Are diseases that occur as a result of inadequate water for personal hygiene, for example, inadequate water for body washing causes skin infections and eye infections.

Water pans: Are excavation constructed either manually or mechanically on a flat or gentle slope with the excavated earth providing an embankment, used to harvesting runoff water majorly in arid and semi-arid lands (ASALs).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

2.2 Surface water sources in ASALs

Access to drinking water is a real challenge in ASALs, which receive annual rainfall of between 250-750mm on average. According to the Kenyan government national policy draft for the sustainable development of arid and semi-arid lands (2004), the water resource developments in ASALs are few and at times priorities are given to highly populated parts. The high temperatures experienced in ASALs causes the drying out of water sources during the dry spell or prolonged drought (NDMA, 2014). Shallow wells are not recharged and the underground aquifers dry quicker than normal (Wekesa & Karani, 2009).

Kenya reported good progress towards access of improved water sources by 2015, with 82% urban and 57% rural population able to access improved water sources. Despite the progress in access to improved water sources, 15% and 28% of the rural population are using unimproved and surface water sources, respectively (WHO&UNICEF, 2015). In rural Kenya, rainwater harvesting technologies have been used to augment the quantity of water available throughout the year in ASALs (ICRAF & UNEP, 2005). Water pans, boreholes and dams have been constructed both by the local individuals and the county governments to aid in water harvesting (Wekesa & Karani, 2009). These have enabled the ASAL communities to enhance their resilience towards the effects of climate change that hardly hit them despite their little contribution towards the release of greenhouse gases to the atmosphere. The enhanced water resource technologies in ASALs have therefore reduced the distances covered to water sources by the resident communities (NDMA, 2014). Despite reduced distances, the water sources are unimproved due to lack of protection and treatment of water at source.

2.3 Distribution of water sources in ASALs

Water resources in ASALs of Kenya are very critical to human and livestock population living in the area. Most temporary water sources in these areas dry up during the dry seasons (Omosa, 2005). Global Positioning System (GPS) have proven to be the most reliable tool of identifying and mapping the field plots of interest in any research project(Johnson & Barton, 2004). Studies have identified use of a global positioning system (GPS) in determining the spatial distribution of water sources (Chormanski *et al.*, 2011). Water sources have been identified and their locations mapped using the Global Positioning

System (GPS) (Simiyu *et al*., 2009)**.** This technique has been used to quantify the spatial and temporal stream flow (Mutiga *et al.,* 2010).

Water sources used by the resident communities of ASALs are mainly water pans, dams and unprotected boreholes. These water sources are categorised as unimproved water sources that are at risk of contamination causing health risks to human health (KNBS & SID, 2013). The identification and location of water sources by a GPS proves to be the most reliable tool in addressing the challenges of household water quantity in a region. Despite the available water sources in the study area, geo-referencing of water pans have rarely been accomplished.

2.4 Water pans

Water pans are formed as a result of excavated earth with embankments used as boundaries. They are the major water resource developments that have been established in ASALs of Kenya. They provide water for domestic, agricultural and recreational purposes. These pans have led to reduced time and effort spent by women collecting water from distant water sources (Nissen- Petersen, 2006; Afullo & Danga, 2013).This is the case in Central and South Baringo where water pans have been excavated to reduce the distance usually covered by the community to the rivers (NDMA, 2014).

A report on water and sanitation, in Kenyan counties revealed that 29.3%, 3.4% and 2.0% of the human population in Mogotio, Eldama ravine and Marigat sub-counties respectively depend on ponds and dams for their domestic water uses (KNBS & SID, 2013).80-90% of water pans and seasonal rivers across Baringo County dry out during the dry season. Therefore, households lack access to clean water for drinking, cooking and washing. This leads to diarrhoeal cases recorded especially during the dry season that is between January to March (NDMA, 2014). Despite the increasing water pan excavations in the study area to increase water accessibility, protection of water sources from external contamination has not been a subject of interest within the Central and South Baringo region.

2.5 Sources of water contamination in ASALs

Surface water remains vulnerable to both natural and man-made contaminations from point and non-point sources (Ichor *et al.,* 2014). Point source of contaminants to water sources include leaking sewerage pipes, man-made ditches for discharging pollutants into water bodies, open defecation practices at water sources and solid waste disposal. Non-point source contamination occurs through run-offs from farm lands, run-offs from construction sites, infiltration from agricultural lands and microorganisms from atmospheric water precipitation. Ichor *et al.,* (2014) highlights absence of natural soil protection and short distances between the point of occurrence of contamination and the points of water extraction, as being responsible for water source contamination.

Despite improved water accessibility provided by various water sources in ASALs, most of them are either unimproved or surface water (WHO/ UNICEF, 2015). Surface water is often filled by precipitation and runoff flowing over the contaminated grounds. Animal droppings, human excreta and other debris often cover the catchment areas, thus can contaminate the water. Fecally contaminated water harbours disease causing organisms that are harmful to human health (Cabral, 2010). Therefore this water is not suitable for drinking but it is suitable for watering livestock, construction work and small scale irrigation (Nissen- Petersen, 2006). Drinking water from open sources that are not treated is not recommended, however, they should either be boiled or disinfected using the solar disinfection technique (WHO, 2011). However, less focus on the prevention of surface water sources from the sources of microbial contaminants have been implemented in the study area.

2.5.1 Bacterial indicators of feacal pollution in surface water sources

Surface water sources remain vulnerable to both point and non-point sources of pollution as the main sources of microbial contaminants. Microbial contaminants are solely responsible for the presence of disease causing organisms in water. Pathogens have been reported to cause a number of illnesses in the world. Ideally such microorganisms are non-pathogenic, do not multiply in waters, occur consistently in pathogen-contaminated water, are reliably detectable even at low concentration, are present in greater numbers and have similar survival rates than the pathogens. The widely used indicator bacteria organisms include total coliform, *E.coli, Fecal streptococci* and *Salmonella species* all of which exist in faeces in high numbers than other intestinal pathogens (Ichor, *et al.,* 2014).

2.5.1.1 Total Coliform

Are a group of closely related genera of rod-shaped bacteria that are widespread in nature. All members of this group can occur in human and animal faeces, but some can also be present naturally in soil, submerged wood, and in other places not associated with the presence of warm-blooded animals. Thus, the usefulness of total coliforms as an indicator of feacal contamination is limited and they are no longer recommended for use with recreational waters. However, because their presence indicates contamination of a water supply by an outside source, total coliforms are still the standard for drinking water. Total coliforms are used to test for the presence of both animal and human feacal pollution (Cabral, 2010).

2.5.1.2 *Escherichia coli*

A subset of total coliform bacteria that can grow at 44.5 °C, are generally from faecal sources. However, even this group contains a genus, *Klebsiella*, with species that are not necessarily faecal in origin. *Klebsiella* are commonly associated with textile, pulp and paper mill wastes, and even leaf litter. Studies show faecal coliforms group precisely *Escherichia coli* to indicate recent contamination. Presence of *Escherichia coli* confirms human feacal pollution of the water sources (Domingo & Ashbolt, 2012: Ogendi *et al.*, 2015).

2.5.1.3 *Fecal streptococcus*

Are a sub-group within the *Fecal streptococcus* group. Enterococci are distinguished by their ability to survive in saltwater, better than *Escherichia coli*. They are typically more human-specific than the larger *Fecal streptococcus* group, thus USEPA recommends Enterococci be used as the indicator of human health risk in salt water used for recreation, and they can be used for fresh water as well.

2.5.1.4 *Salmonella species*

The coliform bacteria can belong to the family *Enterobacteriaceae* which also included pathogenic bacteria such as *Salmonella spp*. These groups are able to survive for different periods in water systems if conditions of PH, temperature and humidity are favourable. The principal habitat of *Salmonella* is the intestinal tract of humans and animals. Salmonellae pathogenic to humans can cause typhoid or paratyphoid fevers *Salmonella species* indicates feacal pollution in drinking water (Cabral, 2010). Less focus have been paid to the presence of these indicator organisms in the water sources used for drinking, cooking and bathing in the study area due to financial constraints and inadequate technical support.

2.6 Household water handling practices

Safe drinking water, proper hygiene and sanitation are the prerequisite for good health among communities. Water safety in a household is dependent on several factors ranging from the water quality at source to water storage and handling practices at home. World Health Organization (2011), states that there is need for a technically and epidemiologically intact infrastructure for local communities to ensure an adequate level of water hygiene in their households. Various home water treatments are available, ranging from boiling water, solar disinfection, use of chlorine, to covering of water storage vessels with clean covers to disinfect and prevent drinking water contamination. However, fewer families have adopted these techniques to help reduce water related diseases in the household. Hygiene practices such as safe disposal of waste, household hygiene and source water protection are important in low income communities to break the chain of infection transmission (Kagwira, 2013).

Point of use (POU) contamination of water has been perceived to be the leading source of microbial contamination of drinking water in the households among communities. These can be attributed to low levels of household knowledge and practices regarding household water handling. Studies in Nepal revealed that there is lack of knowledge and practices in the rural areas regarding water source and sanitary facilities maintenance (Sibiya & Gumbi, 2013). A study in Northern Pakistan revealed that health was not a householder's areas of concern, since they had other pressing needs and that people were not concerned about the poor quality of drinking water as a result of floods (Baig *et.al.*, 2012). A study in Pakistan revealed that 64% garbage was thrown in the fields and 70% of the people were unaware of poor water and sanitation consequences on health (Jabeen *et.al*., 2011). Studies by Kipyegen *et al.,*(2012), revealed that high parasitic infections in Baringo County were associated with inadequate water availability, poor sanitation and lack of water treatment practices in the households. Despite the various studies on the study area to associate disease infections to water handling practices, less focus have been emphasized on the microbiological quality of household drinking water.

2.7 Water related diseases

Water related diseases are illnesses that are caused by consumption, use or drinking of contaminated water. These diseases are typically placed in four categories, these include water borne, water washed, water based and water related insect vectors. *Water borne diseases* are caused as a result of the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses. These include cholera, typhoid, amoebic and bacillary dysentery among other diarrheal diseases (CDC, 2013).

Water washed diseases are caused by poor personal hygiene and skin or eye contact with contaminated water, including scabies, trachoma, flea, lice and tick borne diseases. Without clean water these issues continue to rise. *Water based diseases* are caused by parasites found in intermediate organisms that live in contaminated water, including dracunculiasis, *Schistosomiasis* and other helminthes. *Water related insect vectors* especially mosquitoes that breed within water and transmit diseases such as, dengue fever, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever (CDC, 2013).

Water related diseases have been estimated to be the leading cause of disease and death in the world. 3.4 million People die yearly as a result of water related diseases. Lakes, dams, water pans, boreholes and streams majorly used for bathing, fetching drinking water and defecating are the links between the pathogen transmission and the prevalence of the water related diseases in the human population in the world (WHO, 2008).About 5,000children die daily from water-related diseases mostly in developing countries. Worldometer estimates that a child dies due to water related illnesses such as diarrhoea in every 17 seconds. In 2010, diarrheal illnesses most of which are caused by unsafe water, inadequate hygiene and poor sanitation claimed the death of 801,000children in the world (CDC, 2012).Over 50% of hospital visits in Kenya are for illnesses related to water, sanitation and hygiene (USAID, 2013). Despite the reported water related diseases, the specific categories of water related diseases experienced in the study area have not been explored.

2.8 Prevalence of water related diseases

Prevalence rates of a disease are defined as the proportion of a population found to have the condition/ disease over a given period of time; it includes both the old and the new cases of a disease. Prevalence rates can be estimated by comparing the number of people with the condition with the total number of people studied, and is usually expressed as a fraction, as a percentage or as the number of cases per 100, 1000, 10,000 or 100,000 people. Prevalence rates can be measured either as point prevalence or period prevalence. Point prevalence measures the proportion of a population that has the condition at a specific point in time. Period prevalence is the proportion of a population that has the condition at some time during a given period, for example 12 months, and includes people who already have the condition at the start of the study period as well as those who acquire it during that period. This study sought the period prevalence of water related diseases for the past twelve months in the study area.

The prevalence of water related diseases is mostly attributed to risk factors such as inadequate access to safe drinking water, unsafe disposal of human excreta coupled with poor hygiene behaviour. Water related diseases are more prevalent to people living in rural areas. 2008-2012 Sector plan for Environment, Water and Sanitation reports that, there is high infant mortality, high malnutrition and high maternal mortality rates in ASALs. It attributes this to inadequate basic primary health care services at community levels.This is because they search for drinking water from all sorts of unsafe water sources exposing them to all kinds of dangers related to drinking of unsafe water (Yusuff, *et al.,* 2014). A study conducted in Pakistan revealed stomach problems, allergies, diarrhoea, skin infections and typhoid respectively to be the most prevalent diseases (Jabeen *et.al*., 2011).

A study in Upper River Njoro watershed revealed the prevalence of childhood diarrhoea increased with the number of other illnesses such as coughs, running nose, eye infections and skin infections (Moturi, 2011). A systematic review and mini analysis by Struntz *et al.,* (2014) revealed a reduced prevalence of soil transmitted helminthes infection as a result of using treated water from a pre-intervention prevalence rates of 68.3% to the post intervention prevalence rates of 43.95%. Therefore, the prevalence of water related diseases can be reduced and finally eliminated through good hygienic practices.

ASALs have been the most affected by the outbreaks of water related diseases. Central and South Baringo experiences the dry seasons during the months of January to the beginning of March, and the wet seasons with long rains are experienced during the months of April to August, short rains are experienced from October to the beginning of December (Kenya Meteorological Service, 2014).Diseases such as malaria, diarrhoea, intestinal worms, skin diseases and eye infections were found to be more prevalent in Central and South Baringo during the dry season since water were inadequate and contaminated water (Wetangula *et al.,* 2010). This concurred with a study done in Ijara that revealed, diarrhoeal diseases were more prevalent during the dry months (Njuguna & Muruka, 2011). Malaria have been reported to be most prevalent during the wet months of the year in Githurai, due to the fact that, wet weather enhances the breeding of the mosquitoes (Kaluli, *et al*., 2012). A health survey conducted in Baringo county revealed the incidences of water related diseases were at 17% against the national incidence rates of 15% (Ministry of Health, 2012). Yusuff *et al.,* (2014) attributes the occurrence of water related diseases to drinking of unsafe water and inadequate primary health care services. Supplying clean drinking water and efficient sanitary facilities do not automatically reduce disease or improve health in a community. However, understanding the attitudes and behaviours of a community towards water and sanitation is essential. Therefore, less focus on the seasonal variation of the microbiological quality of water as a contributing factor to the variations experienced in water related diseases in the study area has not been explored.

2.9 Gaps in Literature

Literature review has revealed that prevalence of water related diseases in Central and South Baringo were higher. Most of the risk factors to these diseases were associated with inadequate water supply leading to poor sanitation, personal hygiene and livestock hygiene. However, literature did not cite adequate information on microbial water quality microbial water quality has not been done for Baringo and many ASAL areas, and thus warranting a study of this nature.

2.10 Theoretical Framework: The Integrated Behavioural Model for Water, Sanitation, and Hygiene

The Integrated Behavioural Model for Water, Sanitation, and Hygiene (IBM-WASH) represents the synthesis of these existing behavioral models. Our framework has three intersecting dimensions that influence WASH-behaviors: the contextual dimension, psychosocial dimension, and the technological dimension. The contextual dimension includes determinants related to the individual, setting, and/or environment that can influence behavior change and adoption of new technologies. The psychosocial dimension comprises the behavioral, social, or psychological determinants that influence behavioral outcomes and technology adoption. The specific attributes of a technology, product, or device that influence its adoption and sustained use constitute the technological dimension (Dreibebies *et al.*, 2013). These three interacting dimensions describe mutual interactions between the individual, the behavior, and the environment in which the water handling behavior is practiced.

2.11 Application of the Integrated Behavioural Model for Water, Sanitation, and Hygiene

The contextual dimension represents the background characteristics of the water pan setting, individual, or environment that are often beyond the scope of influence of program activities; however, they exert significant influence on the adoption of specific products or behaviors. These include access to markets and products, access to enabling resources (such as water for handwashing or water treatment), socioeconomic and demographic characteristics, characteristics of the household, and the built and natural environment.

The context in which behavior occurs among the water pan users is dynamic and changes throughout the day – children go to school, adults go to work, household members go to the market. The final level of the Contextual Dimension explicitly addresses these by identifying other opportunities or the lack of other opportunities to repeat and continue practicing an improved behavior. Understanding hand washing behaviors among school children at home must be understood within the context of hand washing water, soap, and facilities available at schools. The benefits of drinking safe water at home will be limited by drinking unclean drinking water at the place of employment. There may be important variations in access to improved technologies and opportunities to practice improved behaviors within the same community setting. Understanding and recognizing these variations is an important part of developing a complete understanding of the contexts in which behaviors occur.

The psychosocial dimension of the IBM-WASH model consists of factors that are amenable to intervention activities of the water pan users, this includes, beliefs, perceived behavioural control, and self-efficacy have been associated with improved WASH practices in a number of specific institutional settings. Factors such as community cohesion and social integration have been found to influence the success of interventions

Technological dimension; all WASH practices, even simple hand washing with soap, require some type of physical product or technology component, and characteristics of this hardware can often have a strong influence on behavioral outcomes. First, the location of the technology required to carry out behavior may facilitate or inhibit practice. Having soap or water at a convenient location for hand washing was associated with improved hand washing practices following fecal contact in rural Bangladesh. The Water and Sanitation Program's (WSP) Global Scaling Up Handwashing Project has identified the importance of enabling products in hand washing, linking hand washing technology and behavior change.

2.12 Conceptual framework

This conceptual framework was a modification derived from the microbial, behavioural and ecological Gostin model (Gostin, 1999). This model has been used by the public health scholars to explain the interrelationship of diseases and health using the three approaches. Microbial model, argues that pathogens are the causes of diseases and the interventions to maintain the health of the population consists of the elimination of pathogens to avoid exposure. The behavioural model argues that the interventions towards controlling diseases should occur at the point of human conduct, whether at individual, group or organizational level. These include promotion of health lifestyles such as; protection of water sources, hand washing practices before or after meals and after visiting a toilet. Proper handling of water at the point of use, this includes covering of water in the household and boiling drinking water to avoid recontamination. The ecological model also argues that most diseases occur as a result of the favourable context in which they exist. For example, fecally contaminated water provides an ambient environment for the thriving of the feacal coliforms (*E.coli*) (Gostin *et al*., 1999).

Water related diseases occur mainly as a result of consumption of contaminated water. The water can be contaminated in various ways from the source to the point of use. This can occur as aresult of unprotected water source, poor sanitation and poor household handling of water. However, some variables herein considered as intervening variables such as population growth, climate change, level of education, government policies, land use, land tenure and culture, influences the occurrences of water related diseases.

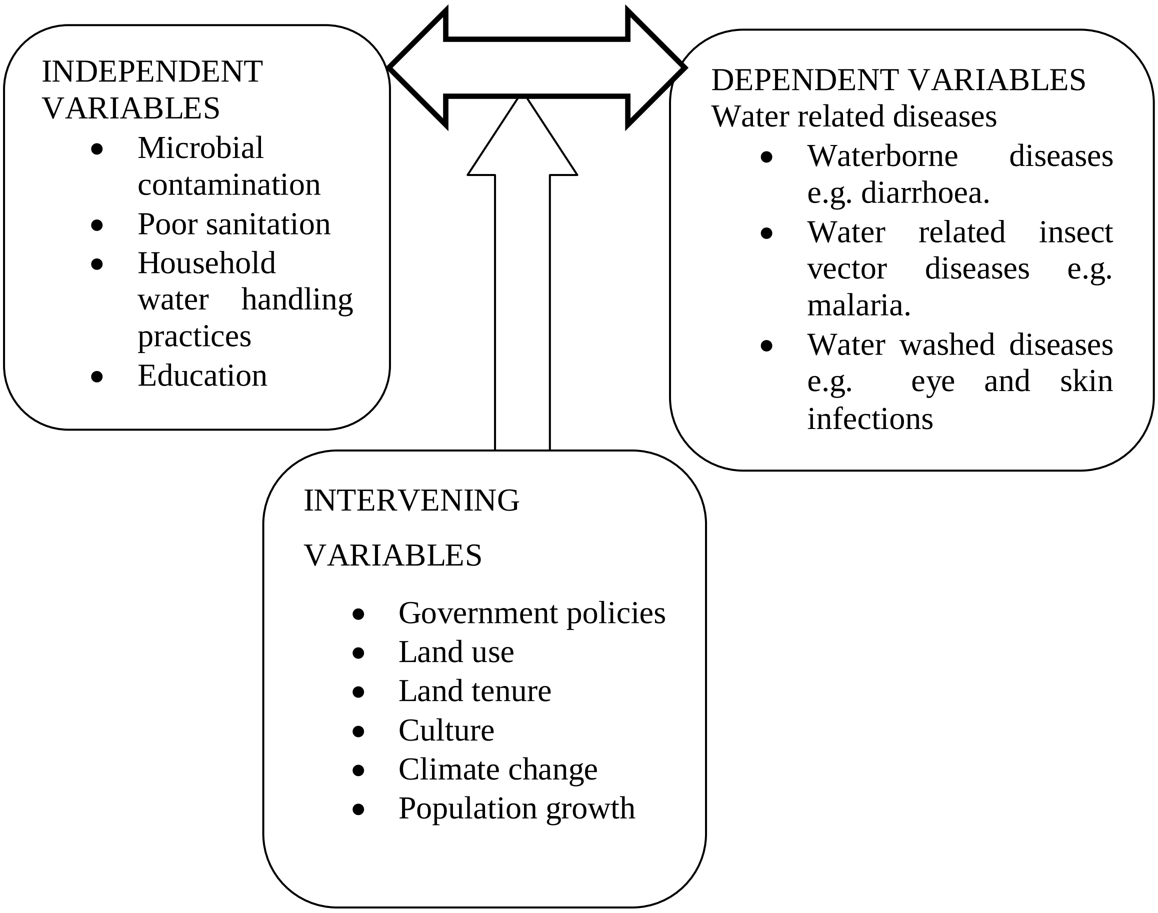


Figure 2.1: Conceptual Framework showing the dependent, independent and intervening variables for this study (modified from Gostin *et al*., 1999)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the study area

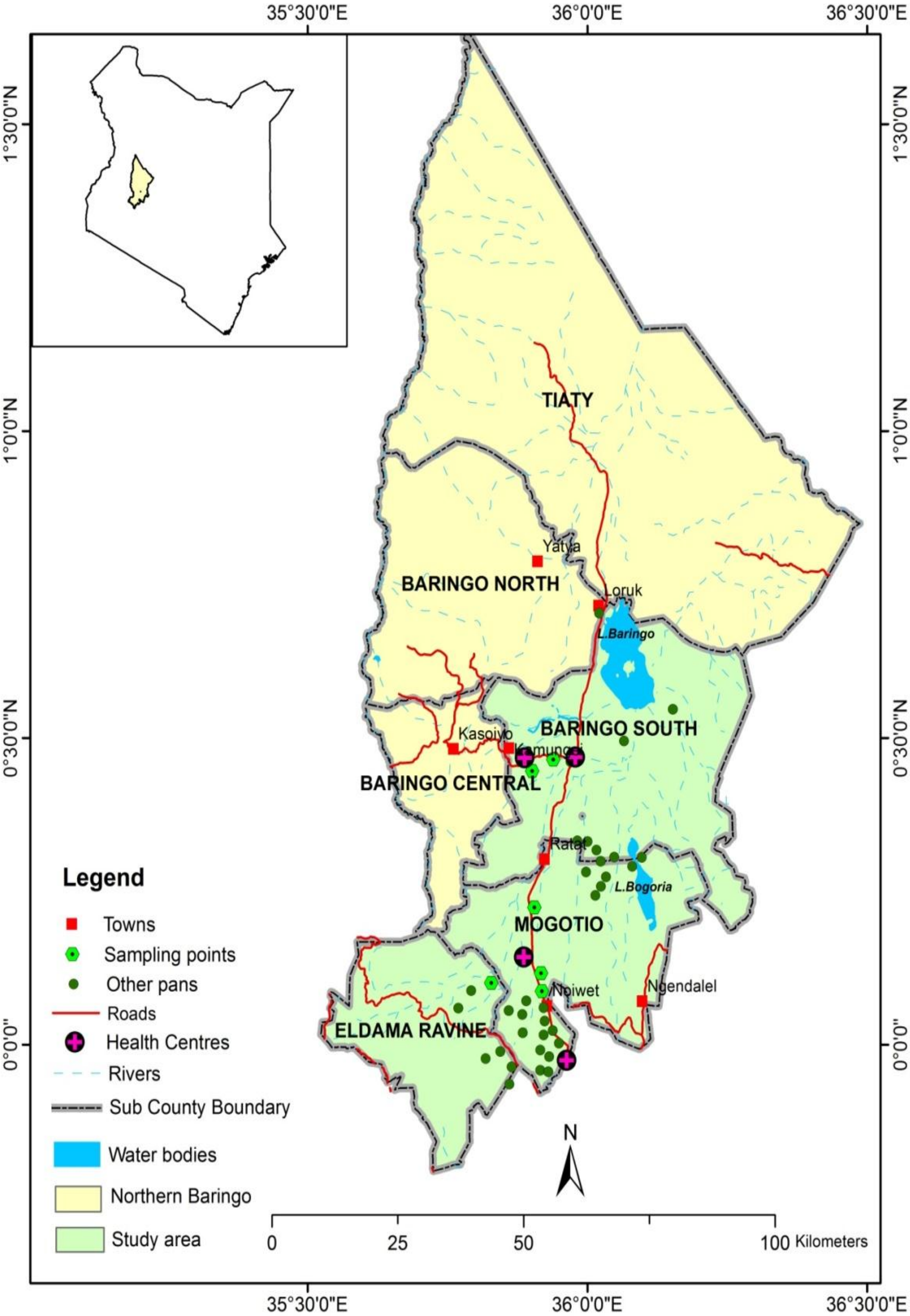


Figure 3.1: Map of the study area (Central and South Baringo, (Source: Author)**.**

ASALs cover about 70% of the greater Horn of Africa and about 90% in Kenya (African Water Facility, 2012). In Kenya, these lands are inhabited by about 70% of the national livestock herd and about fourteen million of the human population. Water scarcity is a challenge due to the erratic rainfalls experienced in this lands (GOK, 2012).

3.1.1 Location

Central and South Baringo County is located at the longitudes and latitudes of $35^0 30'' 0^0$E and $0^0 30'' 0^0$N. Geographically, Central and South Baringo is made up of; Marigat sub-county at the central point of Baringo County, to the south is Eldama Ravine and Mogotio sub-counties which form the Southern part of the county(Figure 3.1).

3.1.2 Climatic conditions

The climatic condition ranges from arid to semi-arid lands. The temperatures experienced ranges from a minimum of 10^0C to a maximum of 350C. Rainfall varies from 1,000mm to 1,500mm in the highlands of Eldama Ravine sub-county, it varies between 250mm to 500mm per annum in Mogotio and Marigat sub-county, respectively. The soils vary in texture from light to medium. They are characterized with low fertility and are subject to compaction, capping and erosion. Heavy clays also occur, making cultivation difficult due to their poor workability as well as problems of salinity and sodicity (UNDP, 2013). Water availability and accessibility is highly variable in the region. Therefore, water pans forms a major water source in some parts of the study area.

3.1.3 Demography

Baringo County has a population of 609, 910(KNBS, 2009). According to the 2009 census, Mogotio sub-county had a population of 60,959, Eldama/Ravine sub-county had 105,273, and Marigat sub-county had 73,177. The populations of the three sub-counties were projected to increase by 2015 as follows; Mogotio sub-county: 74,307, Eldama Ravine sub-county 128,324 and Marigat sub-county 89,200, respectively (Baringo County Government, 2014). The annual growth rate of 3.3% is experienced to be accelerating annually in the County (Baringo County Government, 2014). This heightens pressure on the water resources as well as declining quality and quantity of water and other resources. Water resources are therefore subjected to contamination as a result of the higher population that depends entirely on it.

3.1.4 Socio-economic activities

The population dwelling in Eldama Ravine and parts of Mogotio sub-counties are in AEZ IV practice mixed farming and marginal mixed farming. Whereas, those populations living in some parts of Mogotio sub-counties and Marigat sub-counties are in AEZ V and practice irrigated agriculture and agro-pastoralist for livelihood in the study area (Kenya Meteorological Service, 2014). These activities encourage the use of pesticides to increase the crop yield in the fields and these leads to water contamination as a result of runoff through contaminated grounds.

3.1.5 Topography

The major topographical features in the study area are the plains, the plateau, the foothills and hills in the floor of the Rift Valley. The hills occur in a North-South direction and mainly consist of volcanic rocks, they have steep slopes dissected by gullies (Kimani *et al.,* 2014). The County has different ecological zones, the study area was based on agro-ecological zone IV and agro-ecological zone V.

3.1.6 Geology

The study area is characterised with soils developed in old (Pliocene) volcanic rocks. Due to the prevailing steep and long slopes, the soils are mostly shallow and stony. The major part of the study area belongs to the plateau, which has been broken and tilted by faulting in recent geologic times. Within this plateau, rocky cliffs alternate with gently undulating hills and terraces, covered with shallow and stony clay loam soils.

3.1.7 Hydrology

The study area is a closed basin with two large shallow water bodies: Lake Baringo and Lake Bogoria. Several rivers, most of them seasonal, drain into these lakes. The Perkerra and Molo rivers, which originate from the mountains in the southeast, are the important perennial rivers draining into Lake Baringo, the larger of the two water bodies. River Wesseges is the only important river that drains into Lake Bogoria (Wasonga *et al.,* 2010)

3.2 Research Design

Three research designs namely; case control, observational and cross sectional study designs were used in this study. Case control study design was used since one water pan was protected as the control water pan and the unprotected water pans were referred to as the cases. It was also cross sectional study design since the study was carried out in one point in time (Blumenthal *et al*., 2001). It was observational study design in the sense that there was no manipulation during conducting of the surveys in the households and water pans during the entire period of the study.

3.3 Sampling design

3.3.1 Sampling frame

The sampling frame of this study was the water pans, water pan users and the health centres in Central and South Baringo.

3.3.2 Sample size determination

3.3.2.1 Water pans sample size

The water pans were clustered based on the agro ecological zones IV and V of the study area using the proportionate stratification. Water pans were placed in strata which were the administrative units of the sub-counties in the study area. The sub-counties which were used as strata included; Mogotio, Eldama-Ravine and Marigat sub-counties. According to the unpublished report by the District Water Officer, Koibatek sub-county, there are a total of two hundred and forty water pans in the three sub counties, excavated both by individuals and the government through the Ministry of Agriculture. Mogotio sub-county lies at Agro-ecological zone IV and partly on Agro-ecological zone V. It has one hundred and twenty water pans. Eldama Ravine sub-county that lies at Agro-ecological zone IV has forty water pans. Marigat sub-county that lies at Agro-ecological zone V had eighty water pans.

Using the proportionate sampling formula; $n_w = \frac{N_w}{N} \times n$ (Salkind, 2010)

Where; $\mathbf{n_w}$; is the sample size per strata, $\mathbf{N_w}$; is the total number of water pans per strata. **N;** is the total number of water pans in the study area and n; is the required sample size. Using the required sample size of six, one water pan was sampled in Eldama ravine sub-county, three in Mogotio sub-county and two in Marigat sub-county. Therefore, the water pan sample size for the study was six.

3.3.2.2 Household sample size

Nassiuma (2000) formula was used to determine the household sample size that was used to administer the questionnaires and conducting the sanitary surveys. A preliminary survey was conducted prior the data collection to be able to identify the total number of households using the water pans. The total numbers of household were retrieved from the water pan committee members of the various water pans who verified the number of households using the water pans to be a total of 1130households.

n= $NC^2/C^2 + (N-1)\ e^2$; Where, **N**: Represents the total number of households using the water pans (1130). **n:** Represents the study sample size , C: Coefficient of variation (30%) e: Margin of error(2.9%).

Using the above formula;

$n = 1133\times 0.3^2/ 0.3^2 + (1130-1)\ 0.029^2$

= 98 ~100.

100households were used in conducting the household survey and administration of the household questionnaires. They were proportionately selected from the water pan users using each water pan (Table 3.1).

Table 3.1: Water pan users per water pan within the study area

Name of the water pan(site)	N(Total number of the households using the water pan)	n (Sample size selected from the water pan).
Cheraik	91	8
Kapchelukuny	396	35
Kures	46	4
Chepnyorgin	249	22
Kaptipsegem	57	5
Kinyach	294	26
Total	1133	100

3.3.3 Validity and Reliability

The validity of the study was achieved through ensuring that the questionnaires contained relevant questions to the objectives of the study by the supervisors. The questionnaires were pre-tested for reliability using an approximate of 30households in Tiaty sub-county which had similarities with the study area in terms of water scarcity and reliance on water pans as water sources. The pre-test revealed that the questionnaire was adequate in administering it to the water pan users since the Cronbach’s reliability coefficient was 0.890, therefore it was answering the objective of the study.

Standard instruments and methods were used in water sample collection and analysis to ensure the validity of the study is achieved. The equipment were calibrated properly and sterilized appropriately to ensure reliability of the results. The equipment that were properly calibrated included the pipette syringe, GPS and WTWO microprocessor. The sampling bottles, incubators and the membrane filters were sterilized to prevent contamination of the water samples. Replication of water samples was done using the standard membrane filtration technique provided by the APHA, (2005). This was done to achieve precision and accuracy in the results.

3.3.4 Sampling procedure

3.3.4.1 Field survey

During the water pans observation visit, GPS was used to map the location of the water pans and observation schedule was used to characterize the ecological zonations of the water pans in regard to the types of riparian vegetation cover and soil types present at the water pans. Sanitary surveys were used to assess sources of microbial contaminations and how these factors could influence the occurrences of water related diseases. The surveys were also used in assessing the sanitation of the households. Checklists were filled by the researcher upon visiting the households and the water pans through observation.

Survey questionnaires were used to acquire information on household knowledge, attitude and water handing practices of the sampled households in regard to water handling and water related illnesses at the household level. This was administered to the over 18 years individuals found at the household through interview. This was because they were responsible for most of the water handling and hygiene practices in the household.

3.3.4.2 Water Sampling

Water samples were obtained in triplicate from the following water pans; Kinyach, Kaptipsegem, Chepnyorgin, Cheraik (protected), Kapchelukuny and Kures water pans. For all the water pans, sampling was done twice during the wet season (June – July) and dry season (September- October) 2015, respectively. The sampling sites were located using a GPS. Sterilized 250ml polyethylene water samples were used to collect water samples. This was done 30 centimeters below the surface of the water pans. From the protected water pan, human access point, samples were obtained by first sterilizing the nozzle with 70% alcohol. The sampling bottles were aseptically filled up.

In addition, eighteen households sampled from those that questionnaires had been administered to, three from each water pan, were randomly selected for the study. Household water was sampled from drinking water storage containers in their homesteads. Water temperature, dissolved oxygen, percentage saturation of dissolved oxygen were measured in situ using WTWO microprocessor PH/temperature meter. The meter was calibrated with PH 4 and 7 using standard buffer solutions according to manufacturer's instructions (WTW, Vienna, Austria). The electrode was rinsed with distilled water between samples. Electrical conductivity was measured using a WTWO microprocessor conductivity meter calibrated at 25˚C. All water samples were stored in a cool box with ice and transported to Egerton University, Department of Biological Sciences laboratory for analysis.

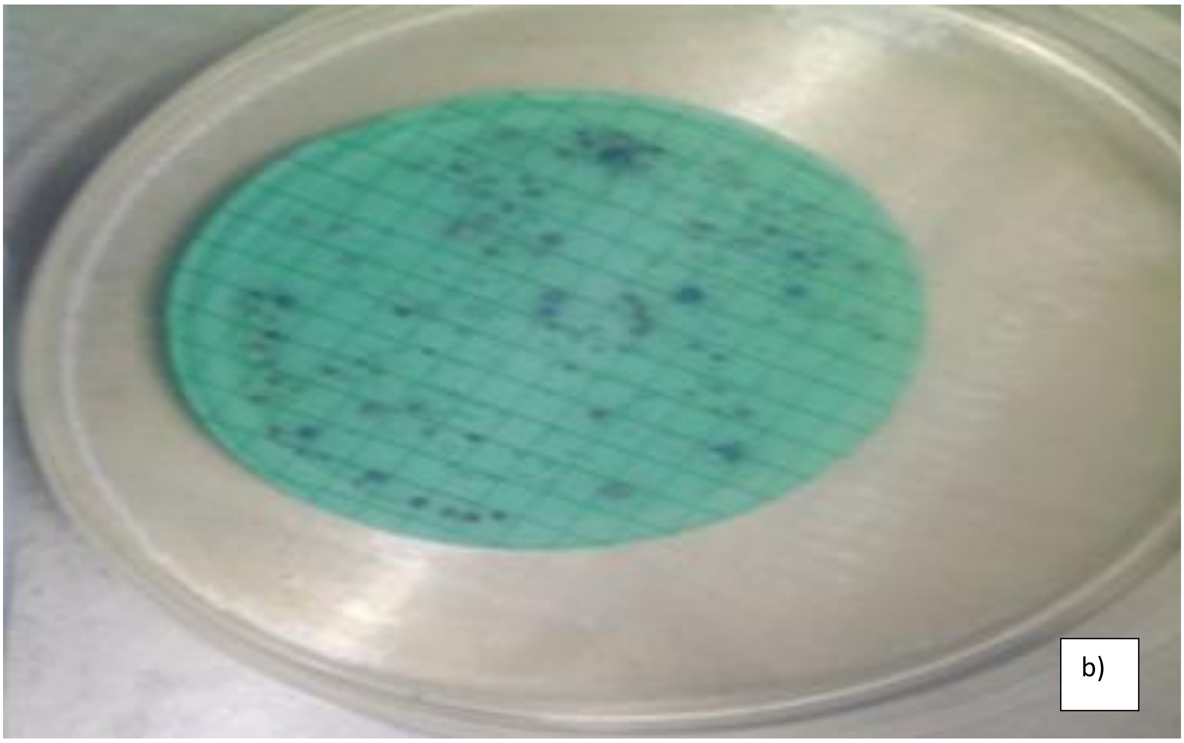
Plate 3.1: Plates of sampling showing: (a) The student researcher reading the physical-chemical parameters using WTWO microprocessor PH/temperature and conductivity meter: (b) The student researcher sampling water at Chepnyorgin water pan

3.3.5 Bacteriological samples analysis

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. Analysis involved the use of Membrane Filtration Technique (MFT) to assay for the presence of indicator organisms. The nutrient and selective media was prepared in advance for each procedure as per the manufacturer's instructions. Serial dilutions of samples were made as appropriate for each test.

3.3.5.1 Membrane filtration technique

Aseptic filtration was done separately for each dilution by passing the sample through a membrane filter (47mm diameter, 0.45µm 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. For total coliforms and *Esherichia coli* counts, filters were placed onto chromocult agar plates and incubated at 37˚C for 18-24 hours. Typical colonies appearing pink and dark blue as in plate 2 (b) below were counted as total coliforms. *Escherichia coli* were the blue colonies only. Numbers of cells were expressed as colony forming units per 100ml (APHA, 2005). For *Fecal streptococcus* counts, filters were placed onto M-enterococci agar plates and incubated at 35˚C for 24-48 hours. Typical colonies appearing pink as in plate 2 (c) below were counted as *Fecal streptococcus* and numbers expressed as CFU's /100ml (APHA, 2005). For *Salmonella* counts, filters were placed onto Salmonella-Shigella agar plates and incubated at 35˚C for 24 – 48 hours. Typical colonies appearing black as in plate 2 (d) below were counted using a colony counter as Salmonella species.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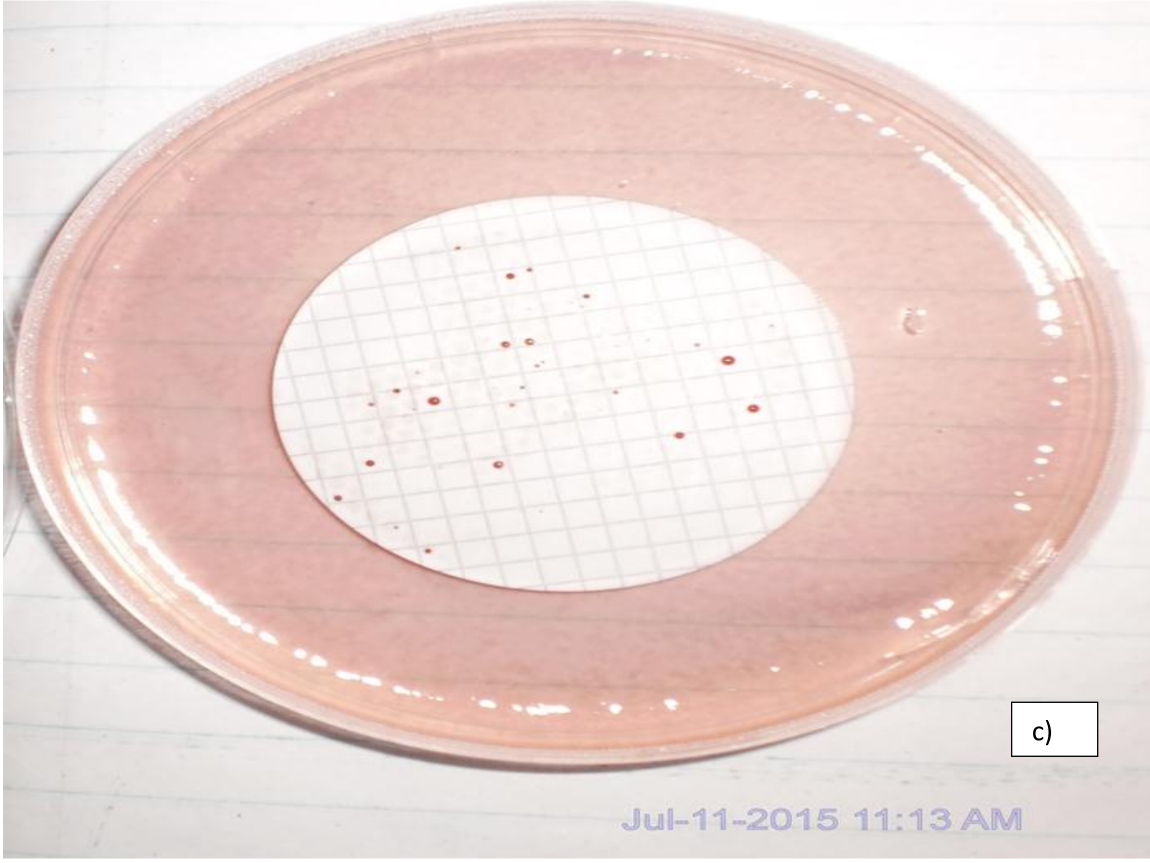
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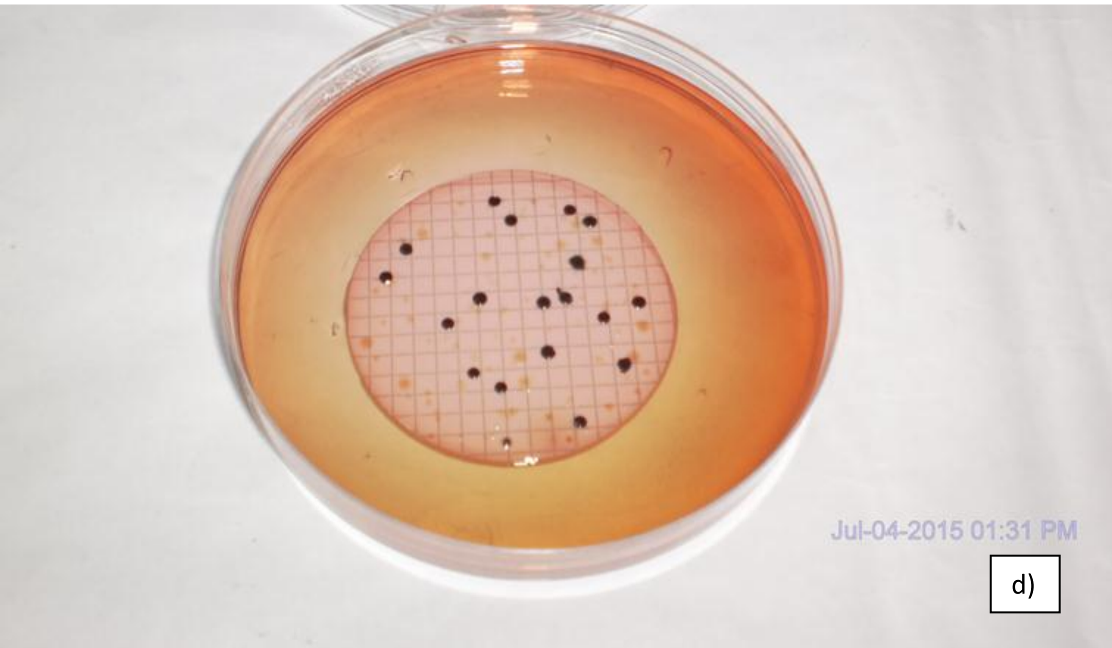


Plate 3.2: Plates of MFT showing CFUs. (a) Membrane filtration technique (b) Total coliform and *Escherichia coli,* (c) *Fecal streptococcus* (d) *Salmonella species* (e) Colony counting by the student researcher using a colony counter.

The colonies which gave 30-300colonies per plate were used. The total bacterial count in every 100ml was calculated using the formula:

$$\frac{\text{Total colony count}}{\text{Volume filtered}} \times 100\text{ml}$$

3.4 Health records

Data on the incidences of water - related diseases for the past one year(April,2014-April, 2015) were collected from the existing health records in AEZ IV (Mogotio and Emining health centre) and those in AEZ V (Kimalel and Marigat Health Centre) within the study area**.** Interviews were conducted by the researcher to the public health officers of each of the health facilities to acquire some more information on the possible factors aggravating the onset of water related diseases within the study area. The acquired data depicted the increased cases of water related diseases in various places of the study area within the last twelve months. The cases were therefore used to calculate the period prevalence of water related diseases during the wet season, dry season and the past twelve months by the student researcher.

3.5 Research authorization

Research authorization was obtained from National Commission for Science, Technology and Innovation (NACOSTI) (Appendix, 6). Informed consent was obtained from the sampled household members who voluntarily participated in the study.

3.6 Data analysis

Normality and homogeneity of variance of the data was tested using the Shapiro Wilk test and Levene's test, respectively. The results revealed a normally distributed data ($P>0.05$) for some of the parameters tested. For the few that did not meet assumptions of normality and homogeneity of variance, the data was log10transformed.

The data was managed using Statistical Package for Social Science (SPSS) statistical software version 20. In all analyses, α was pegged at 5% and 95% level of significance .Data on sanitary surveys (observation checklists) regarding the sources of microbial contamination on the water pans and the households has been presented using descriptive statistics. The same has been done for data on household's water handling practices, knowledge and attitude as well as physical and chemical parameters. In addition to descriptive statistics, T-test were used to determine the difference between the spatial and temporal variations using the pooled counts of the Total coliforms, *Salmonella species, Escherichia coli* and *Feacal streptococcus species* from all sampling sites of the protected and unprotected water pans ($p<0.05$). Spearman correlation was used to determine the relationships between the physical chemical and microbial characteristics of the water pans. Simple linear regression was used to determine the relationship between microbiological water quality and the prevalent water related diseases in the study area (Table, 3.2).

Table 3.2: Data analysis table

Research questions.	**Variables**	**Statistical tables**
What are the sources of microbial contamination of the selected water pans?	Water pan protection Human and animal fecal matter	Descriptive statistics
What are the locations of the water pans in the study area?	Locations of the water pans	Descriptive statistics
What are the spatial and temporal variations of feacal coliforms (*E.coli*), *Feacal streptococcus*, Salmonella species and total coliforms of the water pans?	Spatial variations of: Total coliforms Feacal coliforms(*E.coli)* *Salmonella species* *Fecal streptococcus*	Descriptive statistics (Mean ±SE) T-test Spearman correlation
What are the household's knowledge, attitudes and handling practices on drinking water?	Household knowledge and attitudes on drinking water	Descriptive statistics
What are the prevalence rates of water related diseases?	Prevalence of water related diseases. Microbiological water quality at source and point of use.	Descriptive statistics Simple linear regression

CHAPTER FOUR
4.0 RESULTS AND DISCUSSIONS

4.1 Demographic information

Out of the 100 respondents used in the study 35% (n=35) were male and 65% (n=65) were female. The respondents were in the age bracket of 31-40(32%) and 21-30(30%) years of age respectively. The age bracket of the respondents depicts a younger and youthful age of most of the resident communities in the study area. This was slightly higher than the national age bracket of 31-40(14.5%) and 21-30(18.1%), (KNBS, 2015).The major source of income of the respondents were mainly small scale farming (60%) and business (12%), where as the rest of the respondents had varied jobs including police officer, blumpers, and public health officers among others.

The level of education of the respondents ranged from those who did not attend (6%), primary level (45%), secondary level (35%), tertiary colleges (11%), and only (3%) having attended the university level. The 2014 National Demographic and Health Survey showed that 5% of Kenyans had no education, 23.4% had primary level and 45.4% had secondary school education and above. From this survey, the level of education in Central and South Baringo was lower as compared to the national level of education.

4.2 Water access

4.2.1 Water sources in the study area

Water sources in the study area included; water pans (72%), boreholes (16%), rivers (7%) and tap water (2%) (Figure, 4.1). Water pans are open surface water and prone to contamination as shown in plate 4.1 and 4.2, respectively. A total of 1133 households depended on the sampled water pans for their daily uses (cooking, drinking and bathing) (Table 3.1). Eighty four thousand livestock depended on the same water pans for watering (Table, 4.2). The population depending on the water pans for domestic uses were much higher than the national value for the percentage of people using unimproved water sources. WHO/UNICEF (2014) report indicates that 48% of the Kenyan population uses unimproved water sources. Similar studies by Kioko & Obiri (2012) indicated that 51% of the respondents in Kakamega obtained their water from open sources that are prone to contamination. In Tanzania, Briceno & Yusuf (2012) documented that only 49.7 % of the studied population had access to improved water sources, the larger population having been subjected to using unimproved water sources. Use of unimproved water sources for cooking and drinking in the household exposed the household members to consumption of fecally contaminated water causing water related diseases.

Table 4.1: Livestock populations dependent on the water pans in the study area

Livestock types	Number of livestock
Local cattle	11,170
Goats	60,600
Sheep	10,520
Donkeys	2,000
Total	**84,290**

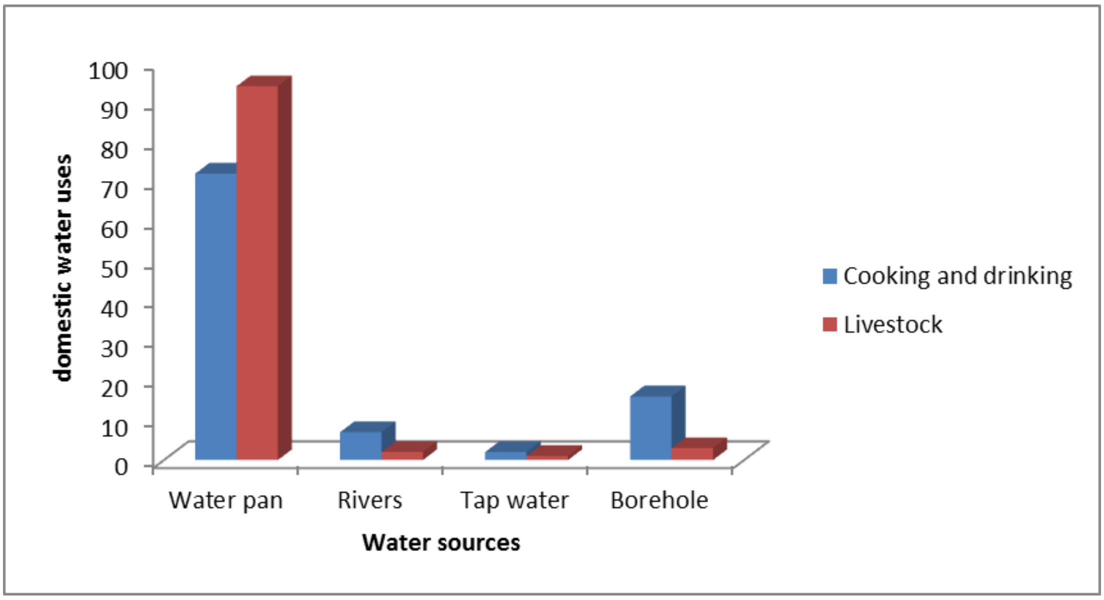


Figure 4.1: Water sources for cooking, drinking and livestock use within Central and South Baringo.

Plate 4.1: Plates showing a) Kapchelukuny, and b) Kures water pan.

Plate 4.2 : Plates showing Cheraik water pan; Water trough and public standpipe.

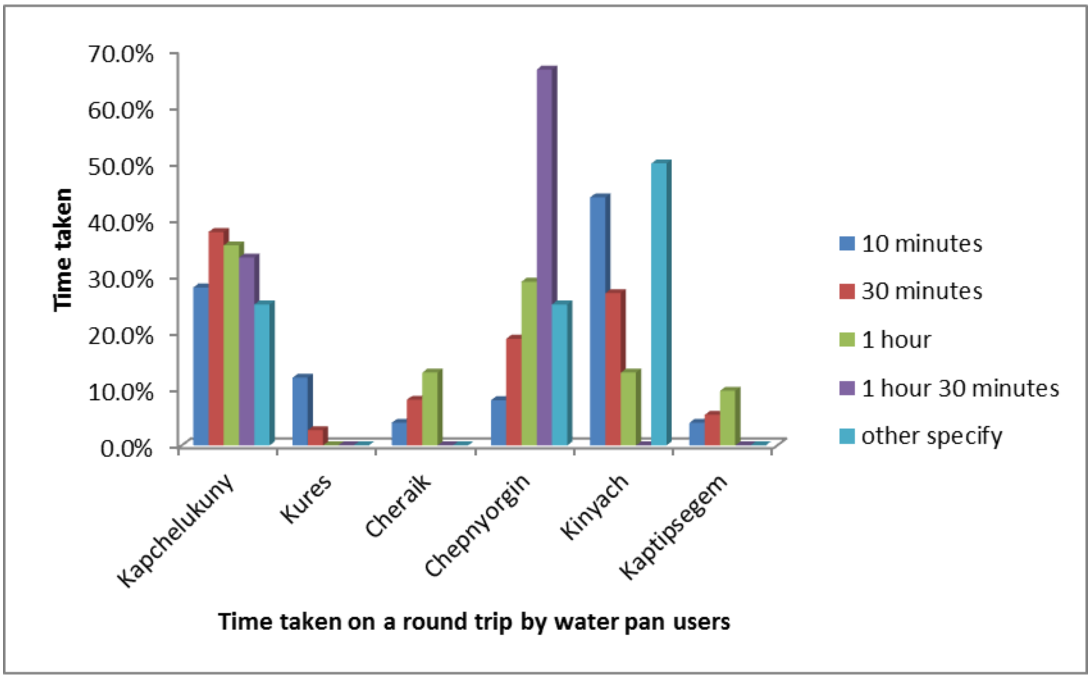
Plate 4.3: Plates showing (a) Kinyach and (b) Chepnyorgin water pans.

Plate 4.4: Plates showing Kaptipsegem water pan.

4.2.2 Time taken to and from the water sources

Water pans have eased the time spent by communities within the study area in search of water for cooking and drinking. On average, 60% of the respondents spent less than thirty minutes on a round trip to the water pan. Approximately 30% of the studied population reported using one hour or more on a round trip to the water source (Figure 4.2). This study findings was in support of a study done by Afullo *et al*.,(2014), who found out that averagely 26.7% of the Kenyan households in ASALs were taking under 30 minutes on a round walking trip of water. Another study by Mohammed *et al*., (2013) found that 41.2% of the respondents in Dukem town Ethiopia were taking less than 30 minutes in one round trip to obtain drinking water in their households.

Despite the efforts to increase water accessibility to the study population, some of them are still spending more time in search of the valuable water resource. These study findings are comparable to other study findings that found out that 42.8% of the households in the Kenyan ASALs took more than one hour to fetch water in a one round trip (Afullo *et al.*, 2014). In Nakuru municipality 55.4 % of the respondents were documented to spend more than 1 hr in one round trip of fetching water (Cherutich *et al.*, 2015). Mohammed *et al.*, (2013) found an average of 17.6% of the respondents in Ethiopia took more than 30 minutes to obtain drinking water on a round trip. Households spending more time to and fro the water sources could be associated with inadequate water available for household chores therefore the likelihood of using contaminated water is enhanced.



igure 4.2: Time taken on a round trip to nearby water sources by water pan users.

4.2.3 Water pan locations

The sampled water pans were located in the arid and semi-arid lands of Central and South Baringo. The location of the sampled water pans were geo-referenced using a portable global positioning system and mapped(Table, 4.2). Kures, Kapchelukuny and Cheraik (protected) water pans were located in agro-ecological zone IV. Their altitude ranged between 1166 m – 1334m above sea level. The soils in this region were observed to be mainly clay loam soil in Kures and Kapchelukuny water pans, whereas Cheraik water pan soils were mainly clay. It was noted that the water in the three water pans were more turbid especially during the rainy season, this could be attributed to soils surrounding the water pans.

Chepnyorgin, Kaptipsegem and Kinyach water pans were located in agro-ecological zone V, their altitude ranged between 1581m-1678m above the sea level. The soils observed around these water pans were mainly brown loam soils in Kinyach water pan, loose clay soils in Kaptipsegem and clay loam soils at Chepnyorgin water pan. These water pans were less turbid due to compact rocky soils observed around them as compared to those in agro-ecological zone IV.

Table 4.2: Water pan locations

Code	Description of the water source	Location
KINY	Kinyach water pan	0˚26′46.85″N; 35˚54′03.94″E
KAP	Kaptipsegem water pan	0˚27′47.21″N; 35˚56′20.88″E
CHEP	Chepnyorgin water pan	0˚22′09.12″N; 35˚56′14.68″E
CHER	Cheraik water pan(Protected)	0˚06′16.45″N;35˚49′34.97″ii7tE
CHEL	Kapchelukuny water pan	0˚06′49.54″N;35˚54′27.71″E
KUR	Kures water pan	0˚05′06.38″N;35˚55′09.09″E

4.3 Sources of microbial contamination of water pans in Baringo County

A sanitary survey was used to assess the sources of microbial contamination of the protected and unprotected water pans in the study area (Table, 4.3). The sanitary survey identifies point and non-point sources of faecal contaminants to surface water that causes human health impairments (Jung *et al.,* 2014). The survey therefore was able to point out some of the sources that may cause microbiological contamination among the sampled protected and unprotected water pans.

Table 4.3: Activities observed around the six water pans during the sanitary survey.

Water pans	**Activities observed around the water pans**				
	Riparian vegetation cover	**Agricultural waste**	**Animal and human waste**	**Water source protection**	**Distinct water points for humans and animal**
Cheraik(protected)	Sparse	yes	None	yes	yes
Kapchelukuny (unprotected)	Sparse	yes	yes	None	None
Kures(unprotected)	Sparse	yes	yes	None	None
Chepnyorgin (unprotected)	Dense	yes	yes	None	None
Kaptipsegem (unprotected)	Sparse	yes	yes	None	None
Kinyach (unprotected)	Sparse	yes	yes	None	None

Land uses such as farming produced pesticides, fertilisers, animal manure and livestock access to water pan banks, could cause foul smell in water and accelerate erosion. Storm water running into the water pan may be contaminated with car oil, dust, soil and animal faeces containing toxicants and chemicals. These pollutants may harbour the presence of faecal indicator bacteria such as total coliforms, *Escherichia coli*, *Salmonella species* and *faecal streptococcus* responsible for causing water related diseases. The protected water pan was observed to contain less of the microbial contaminants on its banks as compared to the unprotected water pans. The survey revealed fewer sources of point source pollution on the protected water pan.

4.3.1 Riparian vegetation

The observed riparian vegetation around the water pans in AEZ IV (Cheraik, Kapchelukuny and Kures) included; *Acacia seyal, Acacia tortilis, Grevillea robusta*, *Senna siamea, Cassia didymobotrya*, *Lantana camara*, *Acacia nilotica*, *Grewia bicolor*, Motomucia (Tugen). *Balanites aegyptica*, *Acacia senegal* and scattered species of *Acacia drepanolobium*. Other species found along the riparian buffers included; Castor plant, star grass (*Cynodon dactylon*), sisal plant, Cassia species (seasonal), Neem tree, *Euphorbia tirucalii* and *Euphorbia candelabrum.* The riparian vegetation cover observed to be common among the water pans in ecological zone V (Chepnyorgin, Kaptipsegem and Kinyach) included; *Acacia melifera*, *Acacia reficiens*, scattered species of *Balanites aegyptiaca*, *Boscia angustifolia, Euphorbia tirucalli, Acalypha fruitcosa* and *Acacia hockii.* Other tree species were *Acacia Senegal* and *Euphorbia candelabrum* .

The sparse and less dense riparian vegetation cover observed along the water pans provided a canopy cover to the underneath herbaceous vegetation. The presence of riparian vegetation is likely to reduce the level of pollutant load transported by run off to the water pans in the study area. A canopy increases the interception level of trees during a rainfall event, increasing the soil moisture and organic matter in soils along the water sources. This increases the absorption level of the pollutants carried by run-off through the riparian vegetation cover (Mureithi *et al.,* 2014).

A mini-review study on contamination of water resources by pathogenic bacteria indicated that pathogens are likely to enter rivers from many potential sources, including lateral inputs from pastures and riparian zones (Pandey *et al*., 2014). Run-off water running through areas that are fully covered or sparsely covered with pastures are less contaminated than cultivated and forested areas (Jung *et al*., 2014).

Sparse and less dense vegetation cover on soils observed along the water pans increased the processes of soil erosion along the banks (Plate 4.1 and Plate 4.2). This was associated with intense rainfall characterised by high intensities and short duration exposing the highly erodible soil to rapid soil erosion. Surface run- off increases the level of sedimentation and turbidity in the water sources, thus introducing faecal materials from contaminated areas to surface water sources (Gichana *et al.*, 2014: Kipkiror, 2012).

4.3.2 Human and animal wastes

Free access by both human beings and livestock to the water pans for domestic water uses was observed among the unprotected water pans namely Kures, Kapchelukuny, Chepnyorgin, Kaptipsegem and Kinyach (Table, 4.3). Inadequate water source protection and high population of human and livestock depending on the water pans was observed to accelerate the rate of microbial contamination in the water pans (Table 4.1). This increased faecal contamination of the water pans by both human and livestock waste (Plate 4.3). This study finding was in support of other study findings; other studies have identified the sources of microbial contamination to water sources to include; uncontrolled disposal of human waste and direct deposits of faecal matter from livestock and wildlife wastes (UNEP, 2010; Anthony & Renuga, 2012; Pandey *et al*., 2014). Human and animal waste increases the level of pathogenic content in the water sources together with inadequate natural soil protection.

Plate 4.3: a) Free access of water pans by human and livestock, b). Child drinking untreated water pan water

*4.3.*3 Low latrine coverage

Thirty five percent of the respondents did not have a toilet facility and therefore used open defecation as method of human waste disposal in the study area. Statistics from Baringo County Annual Development Plan-2015-2016 similarly indicate that 49% of the populations' practised open defecation. Concern worldwide NGO (2012) report, indicated that 88% of the population in Marsabit County practices open defecation. UNEP (2010) reported that one out of every three people who live in rural areas defecate in the open. The poor environmental sanitation in unprotected water pans coupled with low latrine coverage increases the bacteriological contamination of water at source (Table, 4.3).Open defecation practices increases the level of faecal contamination to the water sources during rainy season accelerated by surface run-off. This poses an extreme human health risk and compromises on the quality of water significantly.

4.3.4 Agricultural wastes

The results of the study indicated the presence of agricultural wastes in all the water pans except Cheraik water pan (Table, 4.3). Decomposition of these wastes at the water sources increases the microbial contents at the water bodies. Eutrophication was observed at Chepnyorgin and Kapchelukuny water pans during the rainy season as a result of decomposing nutrients of phosphorous and nitrogen from the nearby agricultural fields. Other studies were in support of this study finding, it was noted that eutrophication of water bodies altered the taste and odour in public water supply (UNEP, 2010: Kipkiror & Towett, 2013). Agricultural activities such as tillage release sediments to the water bodies causing siltation of river beds and water dams.

*4.3.*5 Lack of water source protection

This study identified five water pans among the six that had been sampled for the study were unprotected in Central and South, Baringo. The unprotected water pans were; Kures, Kapchelukuny, Chepnyorgin, Kaptipsegem and Kinyach (Table, 4.3). High population of livestock and human beings accessing the water pans impairs the microbial quality of water (Plate, 4.1). Transmission of zoonotic water related diseases can be experienced as a result of shared water points (Plate 4.3). Free access of surface water by human beings and livestock increases the contamination of a water body through overcrowding at water sources.

4.4 Microbial parameters of water pans in Baringo County

4.4.1 Physical and chemical parameters of water pans in Baringo County

The results on mean values for physical and chemical parameters from the sampled protected and unprotected water pans during the study period as compared to the acceptable NEMA and WHO standards are shown in Table 4.4 below. The mean dissolved oxygen of the protected and the unprotected water pans during the wet and the dry season were below the NEMA guideline values (Table, 4.4). However, the mean dissolved oxygen were much lower among the unprotected water pans as compared to the protected water pan during both the wet and the dry season. This could be attributed to high pollutant load in the unprotected water pans as result of the observed lack of protection and free access by livestock and human beings to the water body thus increasing the level of pollution, lowering the level of dissolved oxygen present in the water pans.

Table 4.4:Physical-chemical parameters of protected and unprotected water pans in comparison to the NEMA and WHO guidelines.

	Results mean in seasons					
Physical chemical parameters	Protected water pan (wet)	Protected water pan (dry)	Unprotected water pan (wet)	Unprotected water pan (dry)	NEMA	WHO
pH	7.50	5.11	7.47	5.16	6.5-8.5	6.5-8.5
Temp(°C)	22.10	28.07	22.10	27.27	22-30	15
DO(mg/l)	5.33	5.68	5.28	5.33	5	5
Cond(µs/cm)	76.27	110.43	122.54	165.42	1000	1000

Electrical conductivity recorded in both the protected and the unprotected water pans were within the recommended NEMA and WHO value during both the dry and the wet season (Table, 4.4).This therefore, indicated that the water from the water pans were potable for domestic consumption. Electrical conductivity were higher in the unprotected water pans as compared to the protected water pans. This could be attributed to excessive pollutant load of water from the unprotected water pans during the dry season which might have increased the concentration of dissolved ions in water.

Temperatures were within the range recommended for supporting the aquatic life forms in both the protected and the unprotected water pans. Similar study in Owena Dam, Nigeria recorded slightly higher mean temperature value of 28.410C (Irenosen *et al.*, 2012).According to Ndubi *et al.,(*2015) study, water pans in Narok South sub-county recorded lower temperatures during the rainy season (12.367 0C) and dry season (22.913 0C).

The temperatures were adequate in enhancing maximum growth rate in fish contained in the water pans, through increased disease resistance and tolerance to toxins.

pH mean values obtained in this study for both the protected and the unprotected water pans were within the recommended limits of WHO and NEMA during the wet season (Table, 4.4). This could be associated with the dilution factor as a result of rainfall event, increasing the pH. During the dry season the pH was far below the recommended guideline value. This could be associated with partial decomposition of organic matter in water thus producing gases that may alter the pH of water in the water pan thus increasing the acidity of water. This contrasted with Ndubi *et al.*, (2015) in their study in Narok South who found out the mean pH of water pans during the dry season to be 8.045.

Table 4.5: Mean±SE values for physical and chemical parameters for water from the sampled water pans (Cher- Cheraik, Chel- Kapchelukuny, Kur – Kures, Chep- Chepnyorgin, Kap- Kaptipsegem and Kiny- Kinyach).

	pH		**Temperature**		**Dissolved Oxygen**		**Conductivity**	
Waterpans	**Mean ±SE**	**Range**	**Mean ±SE**	**Range**	**Mean ±SE**	**Range**	**Mean ±SE**	**Range**
Cher	6.3±0.4	4.4-7.7	27.2±0.8	23.6-31.3	6.3±0.8	3.4-10.8	93.3±5.3	71.2-114.8
Chel	6.2±0.4	4.4-7.7	26.2±1.1	22.1-31.8	4.6±0.1	4.2-5	104.1±1.2	100.0114.6
Kur	6.4±0.3	4.6-7.6	28.4±0.9	24.1-32.6	4.4±1.0	1.2-9.0	180.1±16.5	119-241
Chep	6.3±0.4	4.5-7.5	28.0±0.4	26.4-30.2	7.9±0.2	6.8-9.8	168.7±4.2	152.4-202.3
Kap	6.2±0.4	4.3-7.6	27.6±0.4	26.3-30.1	6.4±0.3	4.0-7.8	117.0±9.0	118.0-147.2
Kiny	6.3±0.1	4.3-7.7	27.0±0.3	22.1-32.6	5.8±0.2	1.2-10.8	135.5±5.2	71.2-241.0

pH plays a very important role in the availability of metals in aquatic environment. Low pH values increases the presence of hydrogen ions in water bodies, whereas, high pH values increases the presence of ammonium ions. The lower pH values could be associated with increased mineral content in the water pan as a result of low dilution factor, since there is no mixing that occurs to aid in acidic ions dissolution. pH showed no significant variation amongst the sampling sites ($p > 0.05$). This could be attributed to the soils forming the base of the water pans; clay soils could have high levels of hydrogen ions thus increasing the acidity nature of the water pan. Similar studies recorded higher pH values in water dams in Samburu district and Narok South sub-county (Cheluget, 2011; Ndubi *et al*., 2015). This could be attributed to the acidic nature of the water pan locations.

Temperature ranged from 22.10˚C and 32.60˚C with Kaptipsegem and Chepnyorgin giving slightly higher values compared to other sampling sites (Table, 4.5). Temperature showed significant variation among the sampling sites ($p<0.05$). This could be attributed to direct insolation as a result of sparse and less dense riparian vegetation cover observed along the water pans. Time of the day and the depth of the water pans when sampling was conducted. Other studies reported lower temperatures in water pans due to the presence of riparian vegetation cover along the water pans therefore the cooling effect lowered the water temperature (Ndubi *et al*., 2015). Water with high temperatures increases the solubility of acidic anions in water, therefore making the water unsuitable for domestic use.

Dissolved oxygen is an indication of the level of pollutants in a water body. High values of dissolved oxygen shows the low levels of pollution in a water body whereas low levels of dissolved oxygen indicates high levels of pollution. The values for dissolved oxygen in the study area ranged between 1.20and 10.84 mg/l (Table, 4.5). Dissolved oxygen showed significant variation between the sampling sites ($p< 0.05$). Similar studies showed a range of 8.720 to 13.180 mg/l of dissolved oxygen (Ndubi *et al.*, 2015).This could be attributed to low temperatures in the water pans that could reduce the solubility of oxygen.

Electrical conductivity of a water body is dependent on the geology of the area. The value of Electrical Conductivity gives an indication of the presence of dissolved ions in water. The values of Electrical conductivity in the study area ranged between 71.20 and 241 µs/cm (Table, 4.5). There was a significant variation of Electrical Conductivity among the sampling sites ($p<0.05$). This indicated the difference of the Electrical Conductivity recorded in the sampling sites, and this could be attributed to the varying concentrations of dissolved solids among the unprotected water pans.

4.4.2 Spatial variation of microbiological parameters of water pans in the study area.

The results of spatial variation of microbiological parameters (total coliforms, *Escherichia coli*, *Feacal streptococcus* and *Salmonella species*) among the protected water pan (Cheraik) and the unprotected water pans (Kures, Kapchelukuny, Chepnyorgin, Kaptipsegem and Kinyach) are shown in Figure, 4.4. The results revealed that there was no statistical significant spatial variation in total coliforms, *Escherichia coli* and *Salmonella species* amongst the sampled water pans ($p> 0.05$). This could be associated with increased fecal matter in the water pans as a result of low latrine coverage observed in the study area, enhancing the proliferation of the faecal indicator organism in all the sampled water pans. Activities such as lack of water pan protection and lack of distinct water points for human and animal use in unprotected (Kapchelukuny, Kures, Chepnyorgin, Kaptipsegem and Kinyach) water pans could lead to overcrowding of water pans with people and animals during water collection, leading to increased faecal contamination at the water source. This could be associated with the presence of increased microbiological parameters in the sampled unprotected water pans.

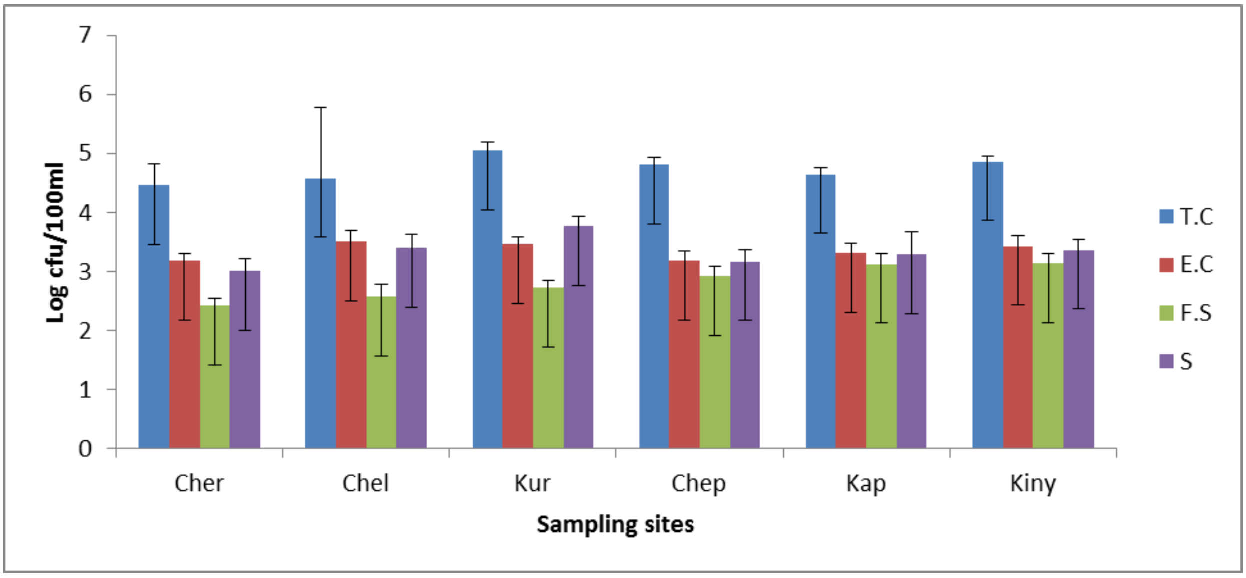


Figure 4.3**:** Mean densities of the microbial parameters (log cfu/100ml) per sampling sites in Central and South Baringo**.**

Legend: T.C (Total coliforms), E.C (*Escherichia coli*), F.S (*Fecal streptococcus*) and S (*Salmonella species*). Cher (Cheraik), Chel (Kapchelukuny) Kur (Kures), Chep (Chepnyorgin),Kap (Kaptipsegem) and Kiny (Kinyach)

An LSD test of microbiological parameters between the protected and the unprotected water pans revealed that there was a statistically significant variation of total coliforms and *Salmonella species* between the protected (Cheraik) water pan and the unprotected (Kures) water pan ($p<0.05$). However, the mean densities of total coliforms and *Salmonella species* were higher in unprotected as compared to protected water pan (Figure, 4.4). This could be associated with the observed animal and human waste, and lack of distinct water points for human and animals in unprotected (Kures) water pan. These activities could be associated to the increase in total coliforms and Salmonella species in the water pan.

Fecal streptococcus showed a statistical significant spatial variation among the sampled water pans (p=0.008; $p<0.05$) (Figure 4.4). However, an LSD test revealed a statistically significant spatial variation between the protected (Cheraik) and the unprotected (Chepnyorgin, Kaptipsegem and Kinyach) water pans ($p<0.05$). The unprotected water pans had slightly higher values of *Fecal streptococcus* than the protected water pan (Figure, 4.4). The results are consistent with a study by Amenu *et al.*, (2013) where protected water sources were observed to have very low levels of contamination. Protection of water pans could be attributed to reduced occurrence of *Fecal streptococcus* in water sources.

The sanitary survey conducted at the water pans revealed poor latrine coverage and lack of distinct water points among the resident communities using the water sources in Baringo County. Sparse and less dense riparian vegetation observed along the water pans reduced the ability of the pollutants transported by runoff to be absorbed; this increases the pollutant load in water. These scenario increases the vulnerability of water to be contaminated with disease causing organism posing a health threat to human health.

4.4.3 Temporal variation of microbiological parameters of water pans in Central and South Baringo.

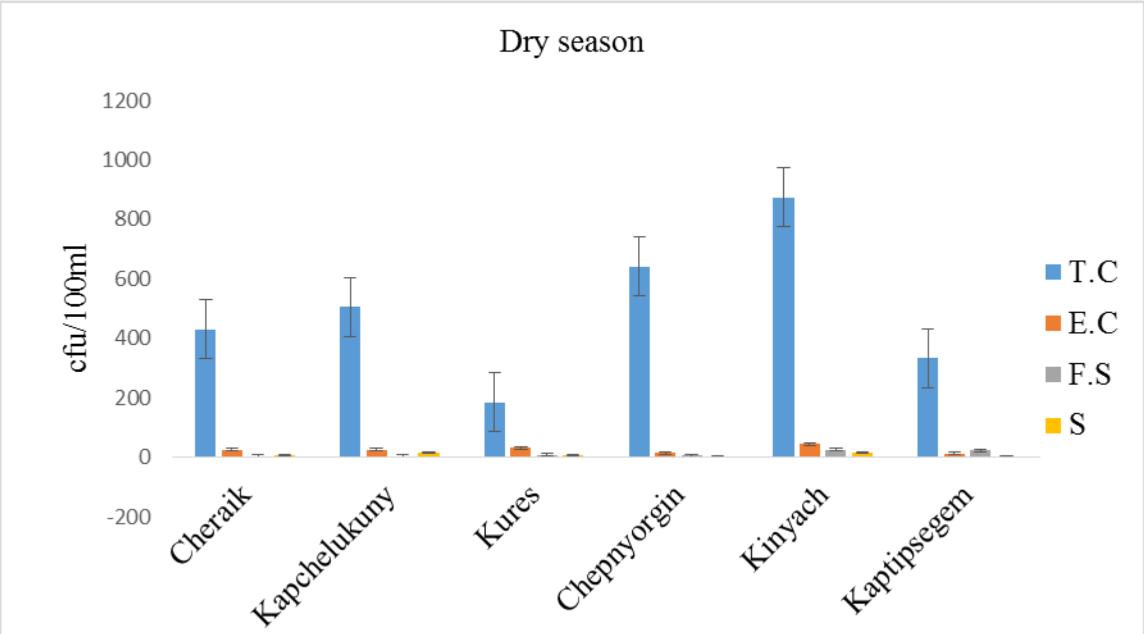


Figure 4.4: Microbial means per sampling site during the dry season.

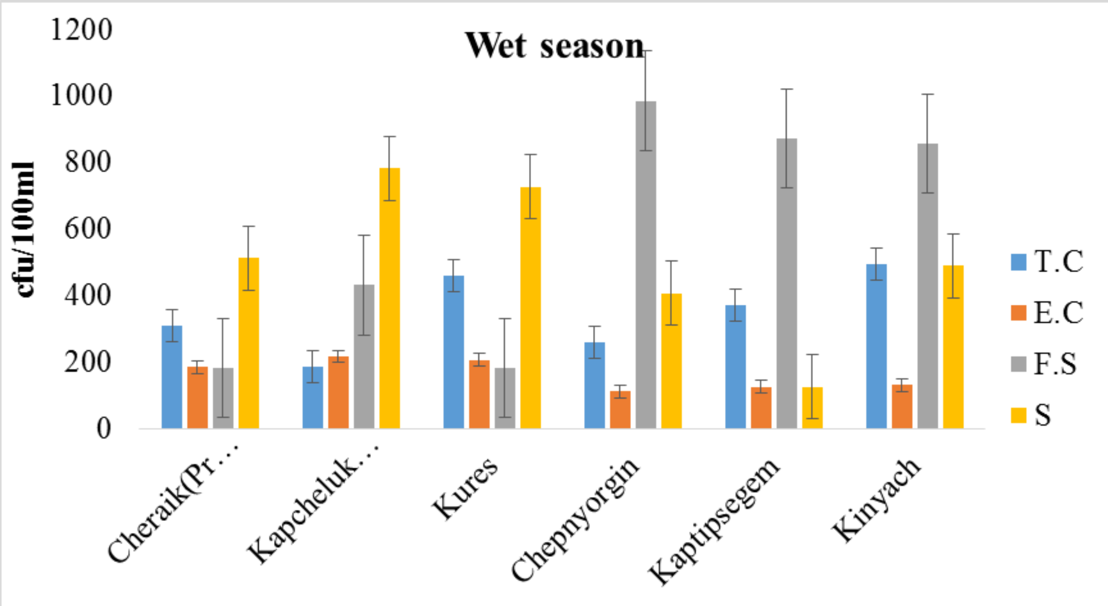


Figure 4.5: Microbial means per sampling site during the wet season.

Season variation of microbial organisms between the protected and unprotected water pans were analyzed using t-test. T-test showed a statistically significant of the microbes during the wet season between the protected and the unprotected water pans ($p \leq 0.05$). Bacterial counts are usually expected to be higher during the wet season because of high rainfall events and are more prevalent in turbid water but high ultra violet radiation from sunlight can reduce the bacterial counts in the rainy season which is associated with high sunshine. *Escherichia Coli*, *Salmonella species* and *Enterococci* count was higher in the wet season than in the dry season which was opposite to Total coliforms, count which was higher in the dry season than in the wet season. The high levels of both indicator organisms found in this study is of a great concern as it can negatively affect the health of the users of water pan resources. This study was in support of a study conducted in Nyangores stream showing presence of *Salmonella species* during the wet seasons (Gichana *et al*., 2014). Edokpayi *et al.*, (2015), in their study in Mvudi River found that *Enterococci* counts were higher during the wet season. Amenu *et al.*, (2014) in their study of microbial quality of water in rural households of Ethiopia recorded a higher prevalence of *Escherichia coli* during the wet season as compared to the dry season. Presence of microbial organisms during the wet season could be due to increased fecal contamination as a result of surface run-off.

The presence of total coliforms during the dry season could be associated with high concentration of coliforms in the soils or the environment. This could be attributed to high pollutant load in the unprotected water pan as a result of low dilution factor. This study finding was supported by Mwajuma, (2010) in her study in selected water sources in

Samburu South, who found out the highest number of coliforms in a dam sample. The concentration of microbial contaminants in water sources during the dry season could be attributed to the concentration of pollutants as a result of low dilution factor.

4.4.4 Correlation between microbiological and physical-chemical parameters of water pans in Baringo County per season.

4.4.4.1 Wet season

Correlation results between the physical chemical and microbiological parameters measured during the wet season are shown in Table 4.6. pH and *Salmonella species* showed a significant positive correlation(r=0.631; p<0.05). The pH range of the water during the wet season were favourable for the growth of *Salmonella species*, this is because Salmonella species can tolerate moderately alkaline pH conditions. pH is important for the growth of aquatic organisms in water (Amanindaz et al, 2015).

Temperature showed significant positive correlation with *Salmonella species* (r=0.587; p<0.05) and *Fecal streptococcus* (r=0.470; p<0.05). Dissolved oxygen showed a significant positive correlation with *Salmonella species* (r=0.582; p<0.05) and *Fecal streptococcus* (r=0.468; p<0.05). Growth of bacteria in water can be related to the existing physical conditions which includes, temperature, dissolved oxygen and pH (Amanindaz et al, 2015).

The presence of Total coliforms and *Escherichia coli* could be attributed to other external factors such as faecal contaminants in water, other than rainfall events. Omondi *et al.,* (2013) in their study in Lake Naivasha basin did not record temporal variation in the density of faecal contamination.

Table, 4.6: Correlation of microbial and physical-chemical parameters during the wet season**.**

	pH	TEMP	DO	CON
T.C	-.226	-.208	-.222	.321
E.C	.076	.073	.071	-.006
F.S	.122	**.470****	**.468****	.167
S	**.631****	**.587****	**.582****	-.207

**Correlation is significant at P<0.05 (2 tailed, N=36).

4.4.4.2 Dry season

Correlation results between the physical chemical and microbial parameters measured during the wet season (Table 4.7). The results showed that Total coliforms and conductivity had a significant positive correlation(r=0.495; p<0.05).This could be attributed to the level of dissolved solids as a result of sedimentation in water pans that enhanced the growth of total coliforms (Amanindaz et al, 2015).

Table 4.7: Correlation of microbial and physical-chemical parameters during the dry season.

	pH	TEMP	DO	CON
T.C	-.171	.161	-.380*	**.495****
E.C	.268	.064	-.158	.129
F.S	.415*	-.018	.175	.114
S	.010	-.191	-.211	.084

**Correlation is significant at P<0.05 (2 tailed, N=36).

4.5 Household knowledge, attitude and water handling practices

4.5.1 Drinking water storage containers and mouth sizes

Mouth sizes of the drinking water storage containers varied from one household to another. The mouth sizes were therefore categorised into medium, wide, small and narrow. Narrow mouth size identified the 5 litre jerry can that is used in the household for the purpose of storing drinking water in the household. Small mouth sizes were used to represent the 10 litre – 35 litre jerry can used to store drinking water in the household. The drinking water storage containers that were categorised as medium were those containers with a minimum volume of 50 litres to a maximum volume of 10000 litres. Wide mouth sizes were used to identify the buckets that were used to store drinking water in the household.

Approximately 71% of the respondents used plastic containers with medium mouth sizes to store their drinking water. This was attributed to the large volume of household water stored and ease in accessibility. Nineteen percent of the study population used jerry cans with small mouth sizes, because of the reduced level of microbial contamination. Six percent used clay pots with narrow mouth sizes to store drinking water in their households, as it keeps water cold and reduces microbial contamination (Figure, 4.6). respondents (74.4%) in Dukem town used plastic jerry cans container to store drinking water.

These study findings were comparable to Mohammed *et al*., (2013) who found out that most

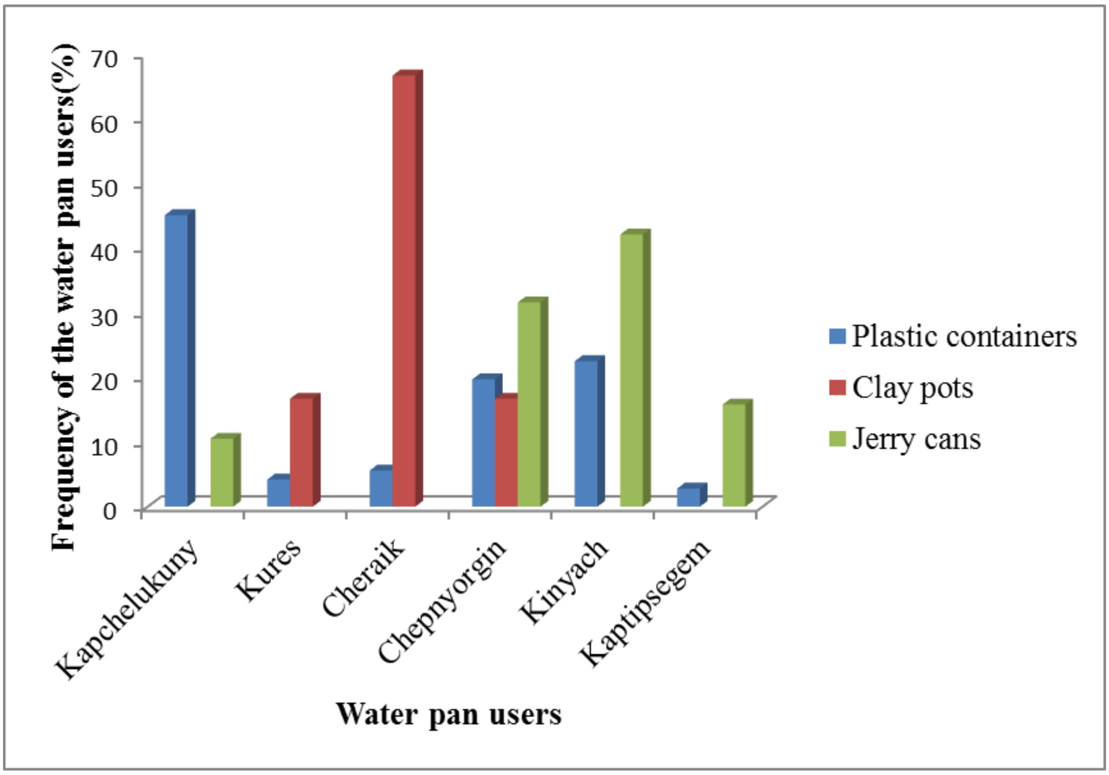


Figure 4.6: Drinking water storage containers used by the water pan users.

4.5.2 Location of drinking water storage container in the house

The storage containers were located in different parts of the room. According to 57% of the respondents their drinking water storage containers were located in the corner of their living room. This was associated to protection of the drinking water storage container from contamination and damage. Seventeen percent of the respondents stored their drinking water storage containers in the kitchen, since it was easily accessed and also used for cooking, however, this was associated with increased level of microbial contamination in water. Fourteen percent of the respondents stored their drinking water storage containers at the door of the living room, since it was easily accessed and the living room was clean and safe from contaminants. This study finding was comparable to a study done in Kakamega that found out that respondents were storing their water in several places in the household to make it cool and sweet for drinking; however they weren't concerned on the microbial quality of water (Kioko & Obiri, 2012).

4.5.3 Water handling in the household

Ninety three percent of the respondents covered their drinking water storage containers. Eighty three percent used the lid of the containers, 4% did not cover their containers and 3% covered them using a clean cloth. These findings were comparable to Mohammed *et al*.,(2013), who found out that 93.2% of the respondents in Dukem town covered their drinking water storage containers. Covering of drinking water storage containers provided a safer way of preventing household drinking water from the risk of microbial contamination.

According to this study, the drinking water storage containers were cleaned as follows; daily (11%), after two days (16%), weekly (42%), and yearly (3%). The cleaning was conducted upon the presence of dirt in the drinking water storage container. On average 52% of the respondents used soap and water, 25% used sand and water whereas 13% used water only to clean their containers. The frequency of cleaning and materials used to clean the drinking water storage containers depict impaired water quality in approximately 60% of the households in the study area.

Forty nine percent of the respondents used a tin to fetch water from the drinking water storage container; increasing the risk of faecal contamination of drinking water. Twenty nine percent of the study population tilted the drinking water storage container to pour water, preventing contamination. Eighteen percent of the respondents used the tap in the container to fetch drinking water from the containers, preventing contamination during water access. Fifty five percent of the respondents reported that adults fetched water for the young children; because children were likely to contaminate drinking water upon access. In 38% of the households children fetched their drinking water for themselves; increasing the chances of fecally contaminating the household drinking water (Figure, 4.7). A study conducted in Nyakach in Kisumu found out that 4.8% of the respondent stored their water in a storage container which had a spigot in it (Wasonga *et al*., 2014). Point of use contamination of water has been perceived to be the leading microbial contamination of drinking water in the households among communities.

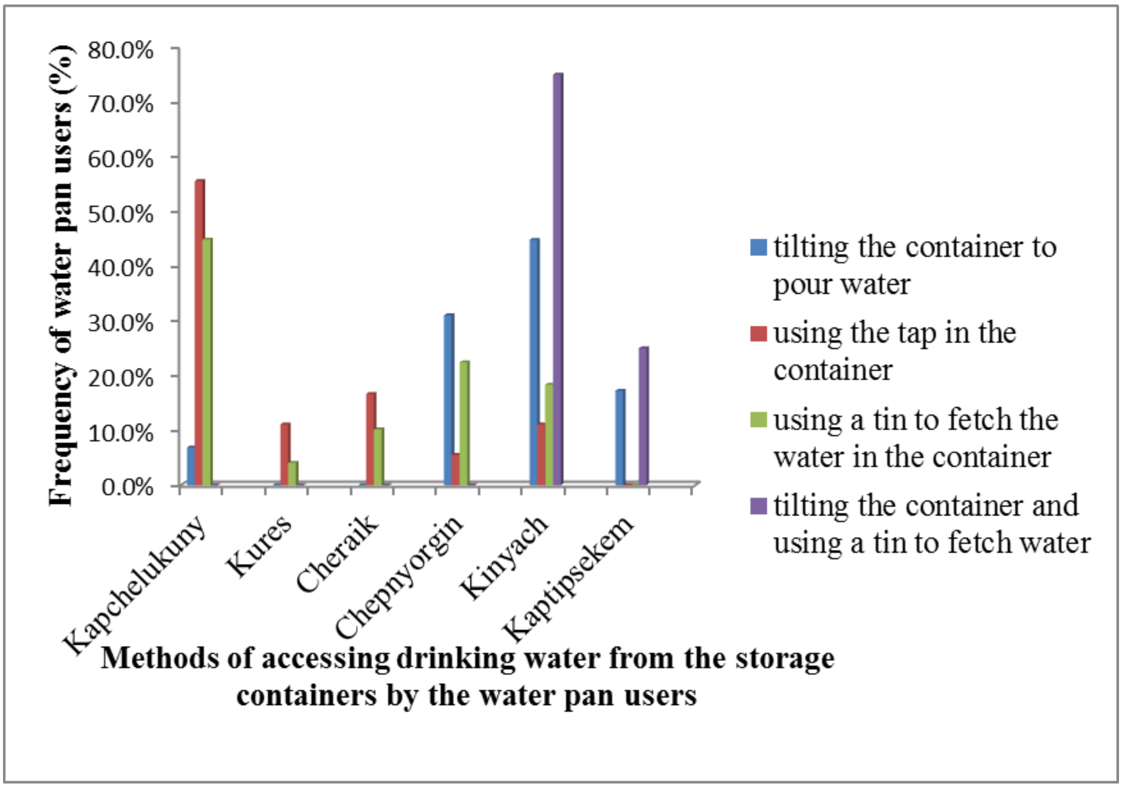


Figure 4.7: Methods used to access drinking water from the storage containers by the water pan users.

4.5.4 Perceptions on water quality and household water treatment in the study area

Thirty three percent of the respondents perceived the water they drink from the water pans as good, 19% perceived them as bad and 48% perceived the water they drink to be fair. The perception of the respondents towards practices that could reduce water related diseases at the household level are shown in Table 4.8. Positive perception were derived from the likert scale answers of strongly agree and agree, unsure perception were derived from neutral responses and negative perceptions were derived from disagree and strongly disagree answers. There was no significant difference between the level of education and the perception on water quality and household water treatment respectively, ($p>0.05$).

Table, 4.8: Perception of water pan users to practices that reduce water related diseases.

Perception	**Boiling drinking water (n=100)**	**Clearing stagnant water (n=100)**	**Sleeping under a treated mosquito net (n=100)**	**Bathing with clean water (n=100)**	**Cooking and drinking uncontaminated water(n=100)**	**Distinct water points at water source (n=100)**
Positive	86	94	98	94	92	95
Neutral	9	2	1	2	2	4
Negative	5	3	1	4	6	1
Total	100	99	100	100	100	100

Averagely, 34% of the respondents treated their drinking water in the study area. This was explained as a way of killing the pathogens in drinking water. On average 19 % of the respondents boiled their water before drinking, despite 86% of the respondents having a positive perception towards boiling drinking water at the household level before consumption (Table, 4.8). On average 7% of the respondents used chlorine and 4% used water guard to treat their drinking water, due to the residual effects they have in killing microbial contaminants, thus safe household water treatment options. This was attributed to ignorance and cultural believe that water is life irrespective of their source and microbial content. This study was supported by other studies, a study in Northern Pakistan revealed that health was not a householder's areas of concern, since they had other pressing needs and that people were not concerned about the poor quality of drinking water as a result of floods (Baig *et.al.,* 2012). Another study conducted in Nepal revealed that there is lack of knowledge and practices in rural areas regarding water source and sanitary facilities maintenance (Sibiya & Gumbi, 2013).

The findings of this study were comparable to Uwimpuhwe *et al*., (2014), in their study in Rwanda that showed 67% of the respondents treated their water. Another study by Onyango & Angienda, (2010) in Western Kenya were in support of this study, where domestic water treatment practices included boiling and use of sodium hypochlorite. Wasonga *et al.,* (2014) in their study found out that commonly used water treatment options in Nyakach, Kisumu County included use of chlorine.

Household water treatment is significant in the reduction of water related diseases such as diarrhoea. Onyango & Angienda (2010) study in Western Kenya deduced that diarrhoea cases were significantly reduced as a result of domestic water treatment. A systematic review and Meta-analysis by Struntz *et al.*, (2014) revealed a reduced prevalence of soil transmitted helminthes infection as a result of using treated water from a pre-intervention prevalence rates of 68.3% to the post intervention prevalence rates of 43.95%. Studies by Kipyegen *et al.*,(2012), revealed that high parasitic infections in Baringo County were associated with inadequate water availability, poor sanitation and lack of water treatment practices in the households. World Health Organization (2011), states that there is need for a technically and epidemiologically intact infrastructure for local communities to ensure an adequate level of water hygiene in their households.

4.5.5 Sanitation and hygiene related information

4.5.5.1 Household solid wastes

Household sanitation is important in reducing the occurrences of water related diseases in a community. Household questionnaires and sanitary surveys found that approximately 89% of the respondents disposed of their household solid waste through burning, thus there was no waste lying at the residents compounds at the time of visit. Eleven percent of the respondents reported throwing their solid wastes away in the open; it was observed that the households had solid wastes lying at their compounds. Unmanaged household solid waste could cause serious health problems in the study area during the rainy season, as the waste are carried off by run-off to the water pans, thus increasing the level of microbial contamination and subsequent water related diseases such as typhoid and diarrhoea. This study were in support of other studies, a study by Karija & Shihua, (2013) linked the high prevalence of typhoid, cholera and diarrhoea in Juba, South Sudan to solid wastes carried off by run-off during the rainy seasons. Wasonga *et al.*, (2014) study in Nyakach, Kisumu County identified 37% households owning a garbage disposal site. Solid wastes also enhance the breeding sites for disease vectors such as mosquitoes and flies.

4.5.5.2 Hand washing

Thirty one percent of the respondents reported washing their hands before eating and 17% washed their hands after visiting the toilet. The respondents reported to have been trained by public health officers, after taking a sick child to the hospital on the importance of hand washing. Thirty one percent washed their hands before eating, this was associated with cultural beliefs and taboos. Other critical hand washing times identified in the study area included; during cooking (4%) and after handling children (9%). This study found that respondents used the following materials to wash their hands; water only (13%), soap and water (86%) and mud and water (1%). Hand washing is important in the reduction of communicable diseases. This lack of basic hygiene adversely affects household water quality as the women dip their hands in storage containers to access water for household tasks. In Masaka Rwanda, 97% of the respondents reported washing their hands before eating, 43% after using a toilet, 20% before preparing food and 31% after handling babies (Uwimphuwe *et al*., 2014).The study also indicated that the respondents used soap and water (87%), ash and water (1%) and water only (12%) to wash their hands. Another study by Wasonga *et al.,* (2014) found that 7% of the respondents in Nyakach, Kisumu County used soap to wash their hands after visiting the toilets.

4.5.5.3 Water-Sanitation-Hygiene (WASH) Awareness

Fifty nine percent of the respondents had received information on personal and food hygiene, whereas, 27% and 13% indicated that they had received information on sanitation and hand washing. However, 12% of the respondents indicated that they had not received any hygiene advice during the past one year (Table, 4.8). This study concurred with Wasonga *et al.,* (2014),who found out that 41.5% of the respondents in Nyakach, Kisumu county reported community health workers/clinics were their main source of information on hand washing, whereas 23.4%, 20.2% and 9.6% indicated that media, schools and community gatherings, respectively, as their sources of information. Hygiene practices at home have been noted to provide a clean environment for children, thus reducing the threats to their health and provides the best chance of a prosperous living (Wasonga *et al.,* 2014; WHO/UNICEF, 2015). The information received by the resident communities is inadequate in reducing the occurrences of water related diseases that occur as a result of improved household hygiene. Increasing the level of community awareness on adequate household, personal and behavioural hygiene is necessary in reducing the prevalent water related diseases in the study area.

4.5.6 Effects of human water handling practices on its drinking water microbial quality

The values for microbiological parameters based on household drinking water pathogenic content are given in Table 4.10. Significant reductions of feacal contaminants in drinking water are expected after collection. However that was not the case, in this study.

Table, 4.9: Mean ±SE of the household drinking water pathogenic content.

Water pan users per site	**TotalColiforms (Mean±SE)**	***E.coli* (Mean±SE)**	***Fecal streptococcus* (Mean±SE)**	***Salmonella* (Mean±SE)**
Kinyach Households	43334.0±17678.8	3063.6±2363.8	9733.3±9458.3	577.3±477.3
Kaptipsegem households	56967.0±1509.5	3126.6±1821.8	1742.3±1253.0	100.0±0.00
Chepnyorgin households	21982.3±11270.8	377.0±153.7	307.0±207.0	100.0±0.00
Cheraik households	59219.6±13275.8	1204.6±776.7	1742.3±548.1	724.3±321.8
Kapchelukuny households	38138.6±4224.8	1261.6±737.3	391.0±30.0	274.0±87.0
Kures households	55135.3±14797.0	5436.0±4408.7	394.0±254.5	4550.0±2568.0

Higher mean values of microbiological pathogenic content from households using water pans were recorded in their drinking water as shown in Table 4.10above. The presence of Total coliforms, *Escherichia coli*, *Fecal streptococcus* and *Salmonella species* were much higher than the recommended WHO values for drinking water for households using both the protected and the unprotected water pans. This indicated poor handling of water at the point of use. Lack of proper hygiene practices such as cleaning of drinking water storage vessels; could lead to the presence of biofilm in drinking water storage containers causing microbial contamination. Water access practices such as dipping of tins and cups to fetch drinking water from drinking water storage vessels by the study population could increase the microbial contamination of drinking water in the household. The study survey indicated that the critical times that majority of the respondents washed their hands was; after visiting the toilet, before and after cooking and after handling children. The study therefore failed to indicate the practice of hand washing before and after fetching water from the storage containers. This low level of behavior change could increase the chances of fecal contamination in household drinking water. Presence of *Escherichia coli* indicates direct contamination with fecal matter, (Ogendi *et al.*, 2015). Presence of *Salmonella species* is an indication of health threat to household water users.

Table 4.10: Household drinking water results (mean), NEMA and WHO drinking water guidelines for microbiological parameters.

Microbiological Parameters	**Household drinking water (Mean)**	**NEMA**	**WHO (2008)**
Total Coliform(cfu/100ml)	4.5×10^{5}cfu/100ml	0cfu/100ml	<1cfu/100ml
E.coli(cfu/100ml)	2.4×10^{3}cfu/100ml	0cfu/100ml	<1cfu/100ml
F. streptococcus(cfu/100ml)	2.4×10^{3}cfu/100ml	0cfu/100ml	<1cfu/100ml
Salmonella species(cfu/100ml)	1.0×10^{3}cfu/100ml	0cfu/100ml	<1cfu/100ml

The values exceeded the recommended NEMA and WHO guidelines as shown in Table, 4.11, below. Our study findings indicated an increase in bacteriological contamination at the household drinking water. Protected water pan presented better water quality at the point of use than water from unprotected water pans. However, the risk of post-collection water contamination contributes to significant microbial contamination occurring inside the transport or the storage vessel. The frequency of cleaning and the materials used to clean the drinking water storage containers determined the presence of biofilm formation inside the storage containers that contributed to increased microbial contamination. Our findings were in agreement with Gundry et al (2006) study on contamination of drinking water between source and point-of-use in rural households of South Africa and Zimbabwe, found out that there was an increase in *E.coli* counts in stored water due to bacterial regrowth or recontamination of water through dipping with hands or cups. Our study therefore, support calls for point-of-use storage and treatment interventions such as home infiltration and chlorination.Presence of microbiological parameters in household drinking water poses human health risk. Prevention measures against the consumption of the fecal matter in the household should be enhanced among the study participants. Point of use treatment and water handling should be effective to eliminate the disease causing organisms in household drinking water.

4.6 Prevalence of water related diseases in relation to microbiological water quality at source and household drinking water (POU).

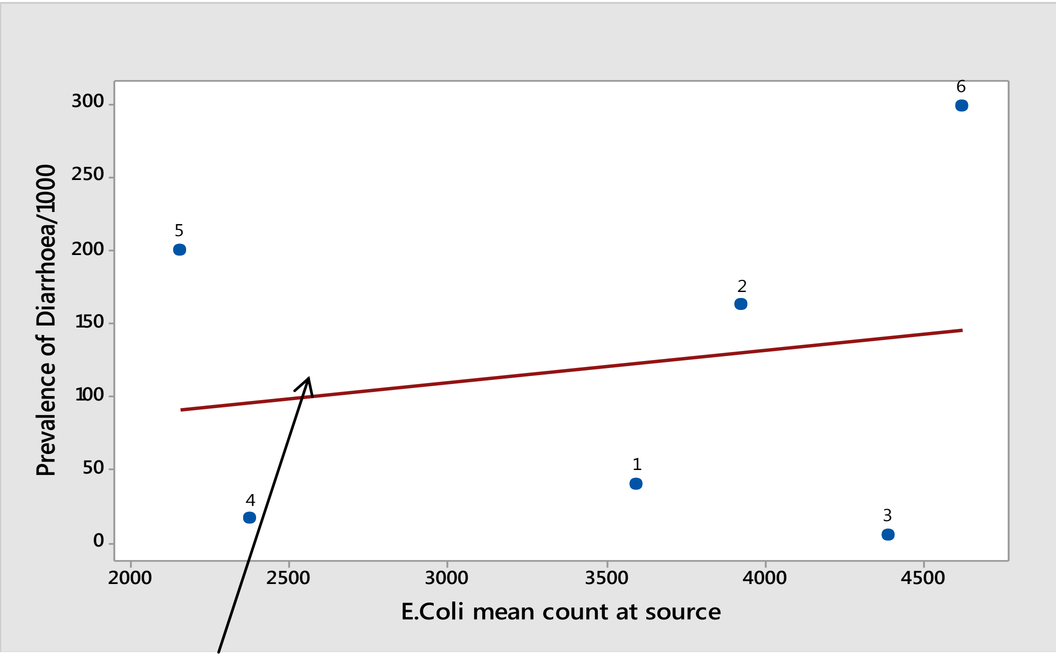
Incidences of water related diseases namely typhoid, diarrheal, skin infections and malaria were retrieved from Mogotio, Emining, Marigat and Kimalel health centres for the past one year(April,2014-April, 2015). The data acquired was used to calculate the prevalence of water related diseases as per the sampling sites. The population at risk were retrieved from the health centres to be 28,234 for all the six water pans users. The prevalence rates of water related diseases acquired in the study area were then compared to the microbiological quality of water pans at source and at the point of use (household drinking water).The prevalence rates of diseases were calculated using the following formula.

Prevalence rate = All persons with a specific Condition at one point in time X K (1000)

Total population at risk (28,234)

4.6.1 Diarrhoea

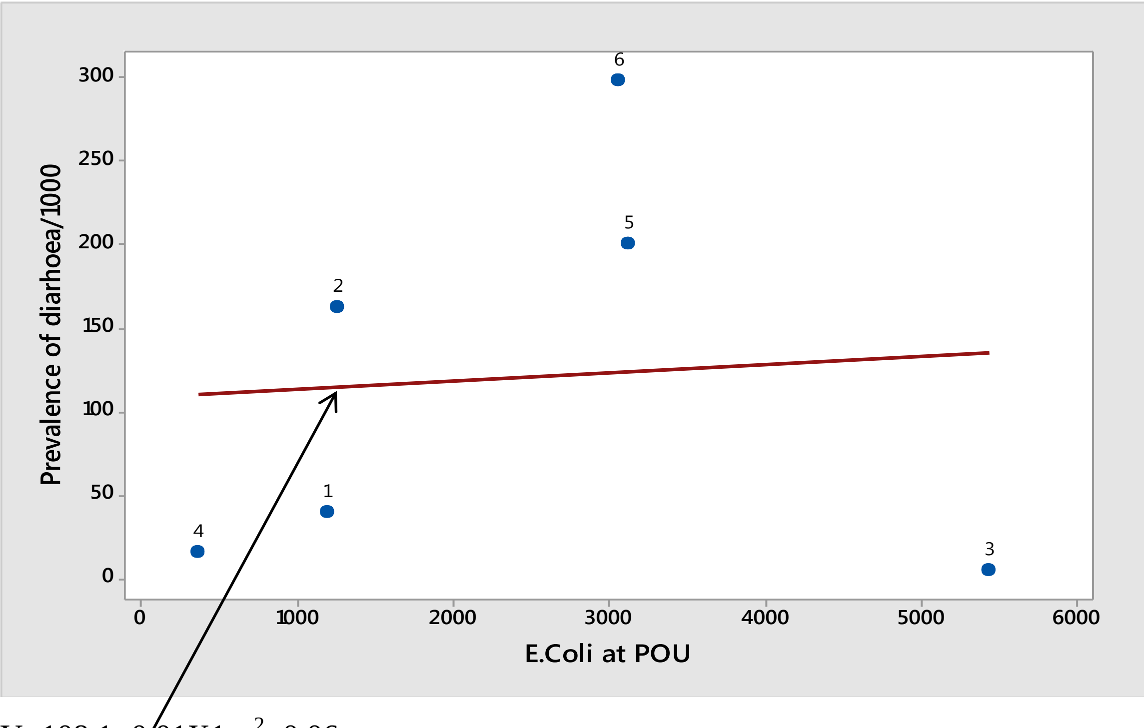
Diarrheal disease prevalence in the study area ranged between 5/1000to 298/1000among the water pan users. There was a significant linear relationship between the *Escherichia coli* content at source in all water pans and the prevalence of diarrhoea (r^2=0.037; $p<0.05$). Kinyach, Kaptipsegem and Kapchelukuny water pan users recorded the highest diarrheal prevalence of 298/1000, 200/1000and 162/1000, respectively, as compared to the other water pan users (Figure, 4.8). This could be associated with feacal contamination of drinking water at the household. This is consistent with other studies; Cheluget (2011) in his study in Samburu district found that water from dams exposed the users to intermediate risk of suffering from water borne diseases. Other studies reveal a stronger association between *Escherichia coli* contamination and diarrheal illnesses among children in Bangladesh (Luby *et al*., 2015). Observing microbial quality of water at source could help reduce the occurrence of diarrheal diseases among water pan users.



Regression fit; Y=42.9+0.02X1: r^2=3.7%

Figure 4.8: Prevalence of diarrhea against the *E.coli* mean count at water pan source. Legend; 1-Cheraik,2-Kapchelukuny, 3-Kures, 4-Chepnyorgin, 5-Kaptipsegem and 6-Kinyach water pans.

Significant linear relationship existed between the *Escherichia coli* in household drinking water and the prevalence of diarrhoea (r^2=0.0061; p<0.05) (Figure, 4.9). Presence of *Escherichia coli* in household drinking water is associated with inadequate household water treatment, low level of household hygiene and poor household water handling practices that increases the level of faecal contamination in household drinking water. Use of unimproved water sources for domestic purposes such as cooking and drinking exposes the users to the risk of consuming pathogens such as *Escherichia coli* which is responsible for gastrointestinal diseases such as diarrhoea.

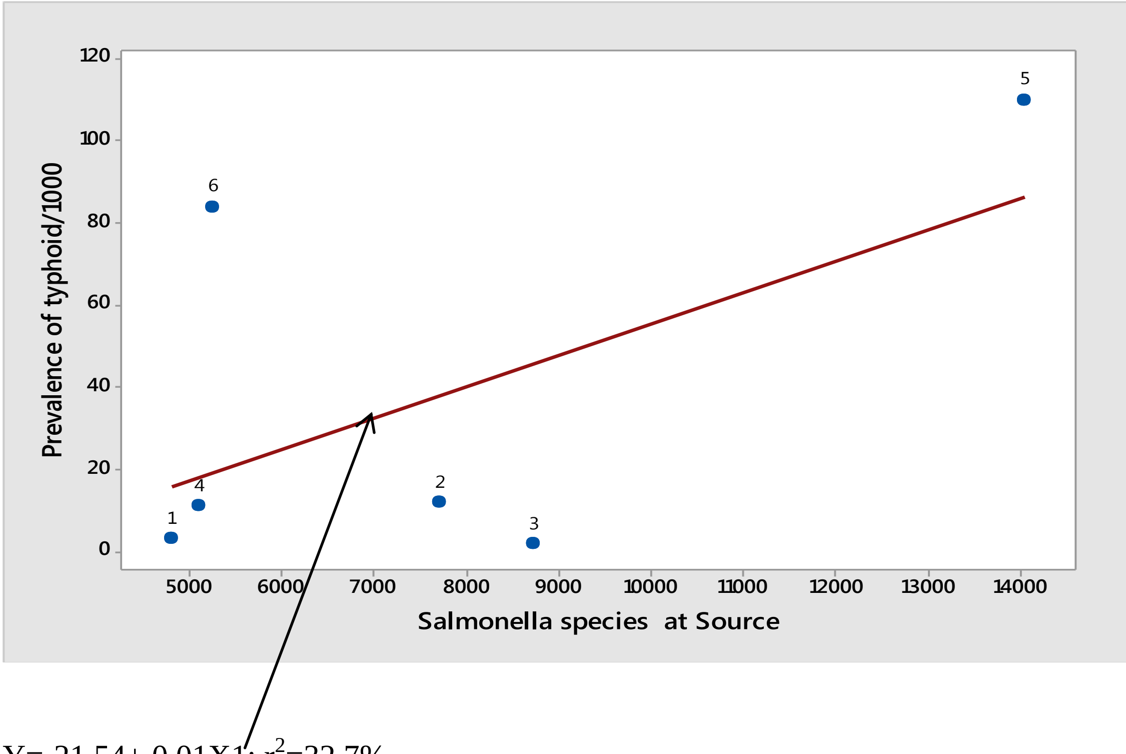


Y=108.1+0.01X1; r^2=0.06

Figure 4.9: Prevalence of diarrhea against the *E.coli* mean count at the Point of use (Household drinking water). Legend; 1-Cheraik, 2-Kapchelukuny, 3-Kures, 4-Chepnyorgin, 5-Kaptipsegem and 6- Kinyach water pans.

4.6.2 Typhoid

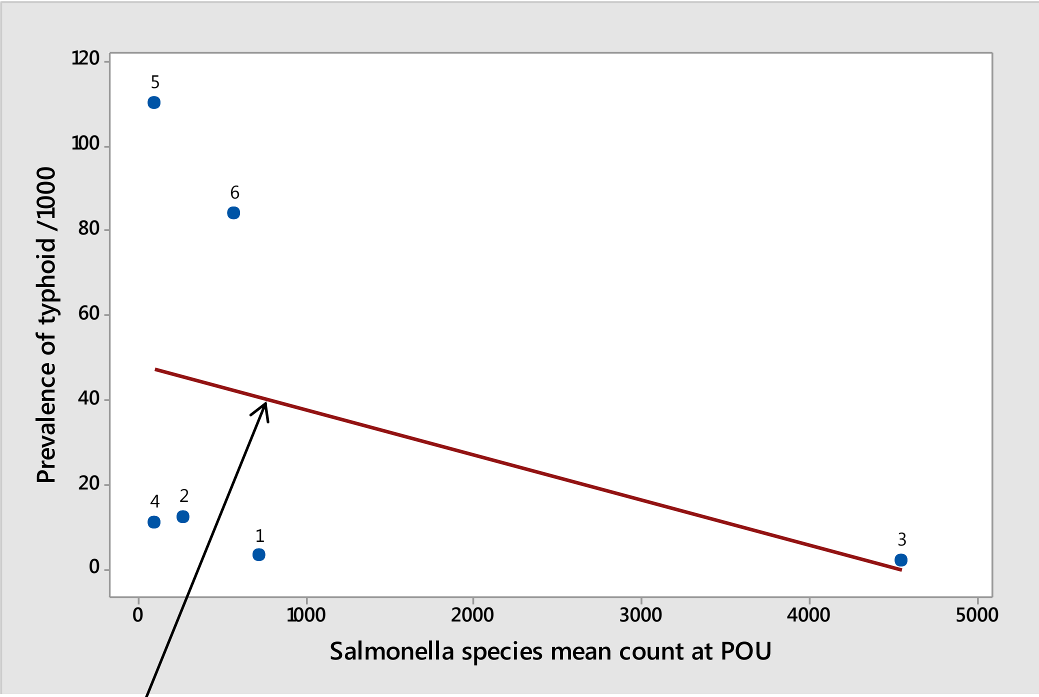
Typhoid prevalence in the study area were high among Kinyach (84/1000) and Kaptipsegem (110/1000) water pan users. Typhoid prevalence in the study area showed a significant linear correlation with *Salmonella species* at the water source in all the sampling points ($r^2=0.327$; $p<0.05$) (Figure, 4.10). This implied that an increase in *Salmonella species* was responsible for the occurrence of typhoid illness among the resident communities. This could be explained by high percentage of respondents who reported not treating their household drinking water before consumption, despite accessing the household domestic water from unprotected water pans in the study area. Low latrine coverage in the study area could also be associated with the presence of *Salmonella species* in the water sources. This study was in support of a study conducted in Juba, that showed typhoid fever having a very high positive correlation with water polluted with *Salmonella species* (Lo-Karija *et al.*, 2013). Provision of adequate human disposal techniques could help reduce the presence of *Salmonella species* in water sources.



$Y=-21.54+0.01X1$; $r^2=32.7\%$

Figure 4.10: Prevalence of typhoid against the *Salmonella species* mean count at water pan source. Legend; 1-Cheraik, 2-Kapchelukuny, 3-Kures, 4-Chepnyorgin, 5-Kaptipsegem and 6-Kinyach water pans.

Salmonella species showed a negative linear correlation with typhoid prevalence at the point of use (Figure, 4.11). An increase in *Salmonella species* in the household drinking water was not necessarily responsible for the occurrence of typhoid among the water pan users. Typhoid prevalence at the households could therefore be associated with other factors apart from the presence of *Salmonella species*, such as immunological characteristics, duration of exposure and age.

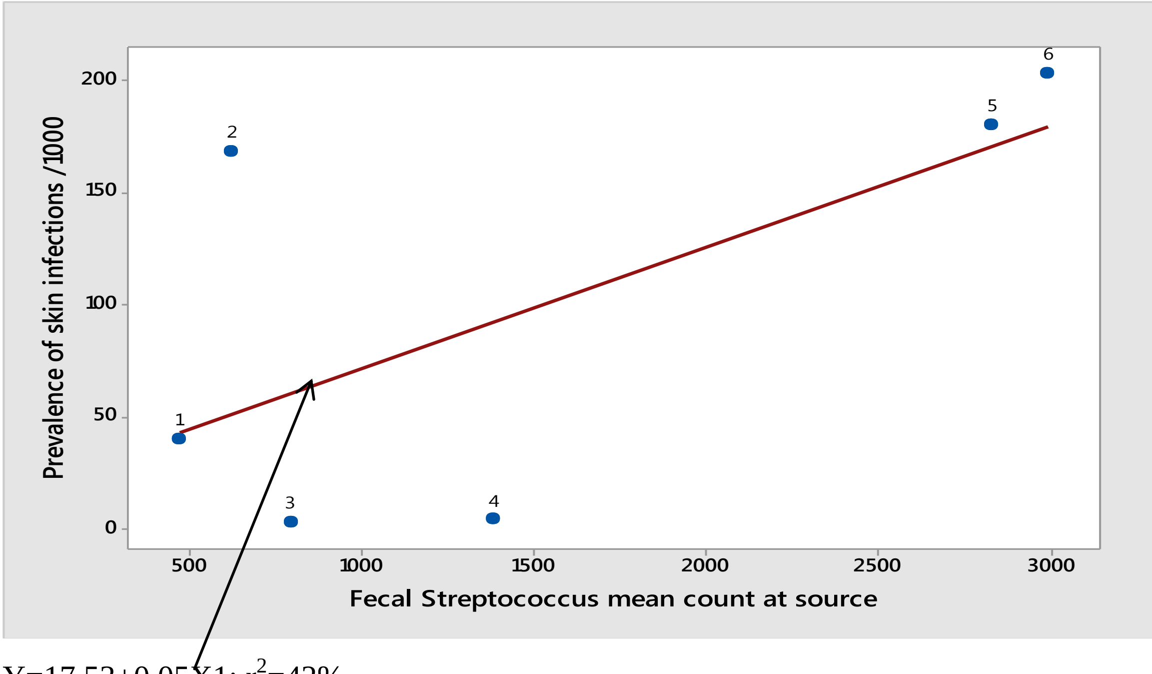


Y=48.18-0.01X1; r^2=15%

Figure 4.11: Prevalence of typhoid against the *Salmonella species* mean count at the point of use (Household drinking water). Legend; 1-Cheraik,2-Kapchelukuny,3-Kures,4-Chepnyorgin, 5-Kaptipsegem and 6- Kinyach water pans.

4.6.3 Skin infection

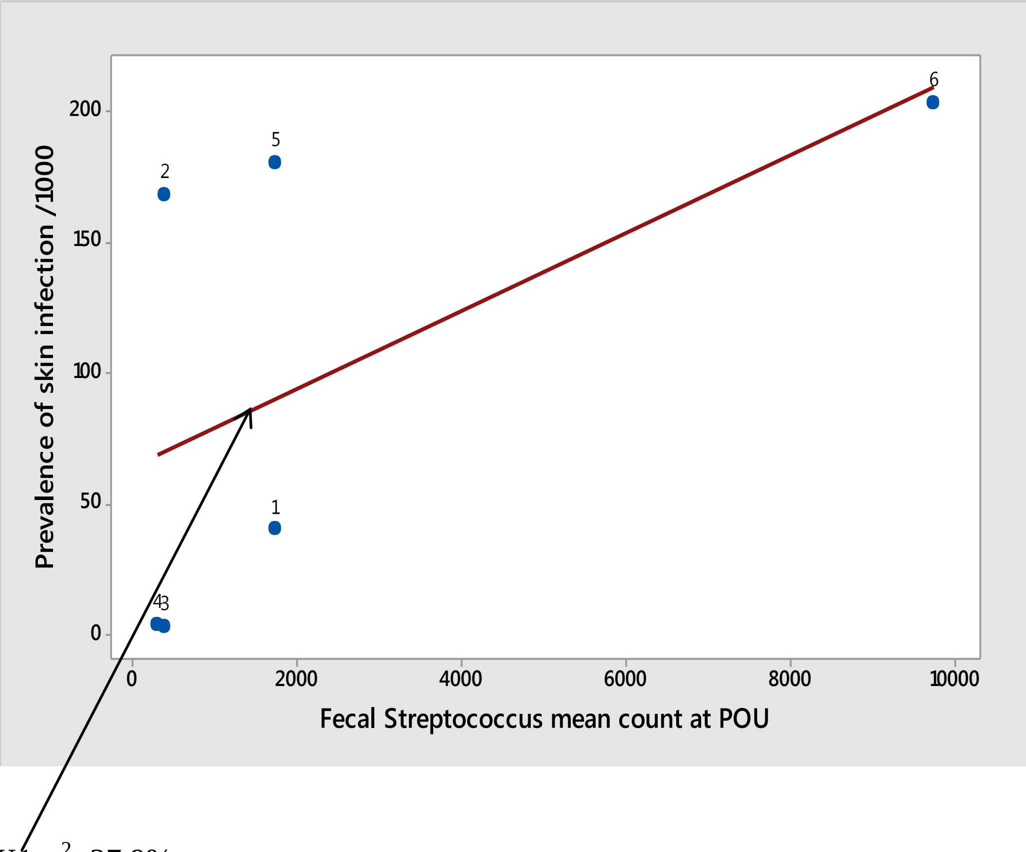
The prevalence of skin infections among the study population ranged from 3/1000 to 203/1000 among the study sites. There was a significant linear correlation between the prevalence of skin infections and the presence of *Fecal streptococcus* at the water source (r^2=0.421; $p<0.05$), (Figure, 4.12). Occurrences of skin infections in the households have been associated with the presence of *Fecal streptococcus* in water used for bathing and swimming. This study was in agreement with other studies that showed significant association between *Fecal streptococcus* and skin related illnesses in marine waters (Yau, 2011). Use of water that is fecally contaminated increases the occurrences of skin related infections in the household and among the water source users.



Y=17.53+0.05X1; r^2=42%

Figure 4.12: Prevalence of skin infections against the *Fecal streptococcus* mean count at water pan source. Legend; 1-Cheraik, 2-Kapchelukuny, 3-Kures, 4-Chepnyorgin, 5-Kaptipsegem and 6- Kinyach water pans.

There was a significant linear correlation between the prevalence of skin infections and the presence of *Fecal streptococcus* at the point of use (r^2=0.341; $p<0.05$), (Figure, 4.13). Inadequate household water treatment and water handling practices could be associated with the presence of *Fecal streptococcus* and the prevalence of skin infections at the household level. Low level of behaviour change such as sharing bathing basins among infected household members could increase the prevalence of skin infection at the household level.



$Y=70.51+0.01X1$; $r^2=27.9\%$

Figure 4.13: Prevalence of skin infections against the *Fecal streptococcus* mean count at the point of use (Household drinking water). Legend; 1-Cheraik, 2-Kapchelukuny, 3-Kures, 4-Chepnyorgin, 5-Kaptipsegem and 6- Kinyach water pans.

Another prevalent disease recorded at the health centres included malaria**.** The prevalence of malaria was not linked to any microbiological agent found in the water body, but to the sanitation of the resident areas of the study population. This was associated to stagnant water pans acting as the breeding sites for mosquitoes, solid wastes found in the sampled household compounds and the water logged soils observed in some of the water pans that could encourage the breeding sites of the mosquitoes. The finding was in congruence with Kimani *et al.*, (2014) who mentioned Malaria to be one of the disease of concern in the Baringo County. Malaria have been reported to be most prevalent during the wet months of the year. This is due to the fact that, wet weather enhances the breeding of mosquitoes (Kaluli *et al*., 2012). The national prevalent rates for diarhoea(6.24%), typhoid(0.02%) and skin diseases(0.23%) (Murray & Lopez (1997). Disease prealence in the study area were much higher than the national prevalence rates.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Based on the findings of this study the following conclusions can be drawn;

Morewater pans are located in agro ecological zone V than in zoneV of Central and South Baringo.

The sources of microbial contamination of water pans in the study area were inadequate protection of water sources, human and animal wastes, agricultural waste, sparse and less dense riparian vegetation cover and lack of distinct watering points.

There was no spatial variation in Total coliforms, *Escherichia coli, Fecal streptococcus* and *Salmonella species* among the protected and the unprotected water pans. Total coliforms and *Salmonella species* counts were high during the dry seasons. *Escherichia coli* and *Fecal streptococcus* did not show a statistically significant temporal variation in mean densities between seasons.

Household water handling practices such as household water treatment and handling of drinking water storage containers were poorly observed among the study participants therefore increasing the presence of fecal contaminants in household drinking water. Water quality at the point of use was highly contaminated than those at source.

Water related diseases prevalent in the study area as a result of fecal contamination in water pans were higher diarrhea(12.2%), typhoid (11%) and skin infections(19% as compared to the national prevalent rates of diarrhea (6.24%) typhoid (0.022%) and scabies (0.24%).

Microbiological water quality contributed directly to the prevalence of water related diseases in the study area, water treatment and water handling interventions should be practiced to reduce the burden of water elated disease among the resident communities.

5.2 Recommendation

Based on the findings of this study the following recommendations can be drawn;

Maintenance of riparian vegetation could significantly help in the absorption of pollutants entering the water pans; this could reduce the microbial content at the water pan.

Establishment of participatory community based initiatives such as committees running water pans to help in protection of water sources to prevent direct access of animal and human beings to the water, designating distinct water points for human and livestock use, establishment of public toilets and bathrooms along the water sources and installing a water treatment plant for the resident communities at village level to make it more effective.

Community awareness on the importance of personal and household hygiene and improved household water handling practices, in reducing the level of microbial contamination in their drinking water at the point of use. Availing and emphasizing the use of affordable, locally available and environmental friendly point of use/household water treatment methods.

Carrying out sensitization campaigns on the risks of water related diseases among the resident communities.

<u>Recommendations for further research;</u>

Protection of water pans could reduce microbial contamination at source.

Further research on the infective strains of *Escherichia coli* and *Salmonella species* should be carried out in the study area.

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APPENDICES

Appendix 1: Water pans Observation Checklist

Checklist to be filled by the researcher when visiting the water pans

Date of Survey ………………………… Place of Survey…………………………

Name of the Surveyor: ………………… Signature……………………………….

1. Do the water pans have riparian vegetation around it?. Yes ☐ No ☐

If yes, please describe the density of the vegetations around the water pans?

…………………………………………………………………………………………

2. Do potential source of surface contamination exist?. Yes ☐ No ☐

If yes, please indicate the sources of surface contamination present.

…………………………………………………………………………………………

3. Is the pan water used by both human livelihoods and the livestock in the area?.

Yes ☐No ☐

a. If yes, are there different water points for human livelihoods and livestock?.

Yes ☐No ☐

4. Are the water pans protected? Yes ☐ No ☐

If yes, Indicate what kind of protection

…………………………………………………………………………………………

5. Please list any other source of pollution (e.g animal excreta, rubbish or human fecal matter within 10m of the water pan?

……………………………………………………………………………………………

6. Is there a risk of mudflow to the water pan? Yes ☐ No ☐

7. Do the water pans have an outlet? Yes ☐ No ☐

Appendix 2: Knowledge, Attitude And Practice Household survey Among The Water Pan Users.

My name is Edith Jepchirchir Kurui, I am a student in Egerton University pursuing Masters of Science degree in Environmental and Occupational Health I am seeking your opinion on water handling and treatment at household level. The information provided herein will be treated as confidential and will be used for academic purposes only.

Instructions; Do not write your name in the questionnaire, tick ( ) for YES and cross (X) for NO for answers in the boxes. Explain your opinion in the spaces provided. To be filled by the household head or the care giver in the family.

1.0. PERSONAL DETAILS (tick in the brackets)

1.1. **Gender**

1. Male ☐
2. Female ☐

1.2. **Age** (Please tick in the space provided)

1. 11- 20 ☐
2. 21 – 30 ☐
3. 31 – 40 ☐
4. 41 – 50 ☐
5. 51 – 60 ☐

1.1 Demographic information

1. What is the size of your family? Males ……… Females ………..
2. Total number of children under 5 years …………………
3. What is the occupation of the household head? …………………………
4. What are the main income sources to your household? ………………………………….

1.4. Education level of the respondents (tick in the brackets)

1) Primary level ☐
2) Secondary level ☐
3) Tertiary colleges ☐
4) University ☐
5) Others specify …………………………………….

1.0 Sources of water

1.1 a). What is the main source of water for cooking and drinking in your household chores?

a) Water pans/dams ☐

b) Bore hole ☐
c) Rivers ☐
d) Tap water ☐
e) Water vendors ☐
f) Others explain

………………………………………………………………………………………………

………………………………………………………………………………………………

…………………………………………………………………………………

b). What is the main source of water for livestock use in your household?

a) Water pans/dams ☐
b) Bore hole ☐
c) Rivers ☐
d) Tap water ☐
e) Water vendors ☐
f) Others specify

……………………………………………………………………………………………

1.2 How long does it take you to walk from your homestead to the water source and back?

a) 10minutes ☐
b) 30minutes ☐
c) 1 hour ☐
d) 1 hour 30minutes ☐
e) Other specify ……………………

1.3 Do livestock drink water from the same point that you use to fetch water?

a) Yes ☐
b) No ☐

2.0Water handling

2.1 What container do you use to store drinking water in the household?

1. Plastic container ☐
2. Clay pots ☐
3. Jerrycans ☐

2.2 Where is your drinking water storage container located in the house

1. At the door of the living room ☐
2. In the kitchen ☐

3. In the corner of living room ☐

4. Others specify …………………………………………………………………

2.3 Do you cover your drinking water storage container?

1. Yes ☐
2. No ☐

2.4 If yes, what do you use to cover the drinking water storage container?

1. Lid of the container ☐
2. Clean cloth ☐
3. Other specify …………………………………….

2.5 How often is the storage containers cleaned?

a) Daily ☐

b) After two days ☐

c) Weekly ☐

d) Monthly ☐

e) Yearly ☐

f) Never ☐

g) Others specify …………………….

2.6 What do you use to clean your water vessels?

a) Water only ☐

b) Soap and Water ☐

c) Ash and Water ☐

d) Mud and Water ☐

e) Sand and water ☐

f) Other specify………………………………………………………………

2.7 How is the drinking water from the storage container accessed?

1. Tilting the container to pour the water ☐
2. Using the tap in the container ☐
3. Using a tin to fetch the water from the container ☐
4. Others specify ……………………………………………

2.8 How do children in your household access the drinking water from the containers?

1. An adult fetches it for them ☐
2. They fetch it for themselves ☐
3. Others specify. …………………………………………
4.

4.0 Household Water treatment

3.1 What do you think is the quality of water that you use at your home?

a) Good ☐

b) Bad ☐

c) Other specify …………………………………………

3.2 Do you treat your drinking water before use at home?

a) Yes ☐

b) No ☐

If yes, how do you treat your water?

a) Boiling ☐

b) Chlorine ☐

c) Solar ☐

d) Filtering by cloth ☐

4.0Hygiene and sanitation

4.1 How do you dispose your waste materials at home?

a. Burn ☐

b. Reuse ☐

c. Recycle ☐

d. Throw away in the open ☐

4.2 What materials do you use to wash your hands?

e) Water only ☐

f) Soap and Water ☐

g) Mud and water ☐

h) Ash and water ☐

i) Other specify....................................

4.3 During which occasions do you wash your hands?.

a) Before mealtime ☐

b) After mealtime ☐

c) Before cooking ☐

d) After using the toilet. ☐

e) Other specify …………………..

4.4 Have you heard any hygiene advice before? Yes ☐ No ☐

If yes, please explain ……………………………………………………………….

4.5 Please list the sources you heard the hygiene advice in the past one year from?

…………………………………………………………………………………………………
………………………………………………………………………………….

5.0Health Related Issues

5.1 Has anyone suffered from any disease in your household in the past one year?

Yes ☐ No ☐

If yes, please list the diseases your household members suffered from in the past one year?

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

1.2 What do you do to prevent children and other members of your household from suffering from any of the above listed diseases in your household?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………..

6.0Knowledge

6.1 Do you have any concern regarding the sharing of the common watering point between both the livestock and the human beings? Explain your answer

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………………………………………………………………………………….

6.2 Do you think drinking water before treating them is harmful to your health? Briefly explain.

…………………………………………………………………………………………………
…………………………………………………………………………………………..

6.3 What do you think caused the illness? Briefly explain

…………………………………………………………………………………………………
………………………………………………………………………………………….

6.4 Do you know of any other disease that can be caused by use of contaminated water for household use? Briefly name them

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

Appendix 3: Household observation checklist

1. What was the mother/care giver doing at the time of arrival in the household?

1. Feeding the child ☐
2. Cooking ☐
3. Cleaning utensils ☐
4. Taking care of the animals ☐

2. What types of toilets are present in the household?

1. Pit latrine ☐
2. VIP latrine ☐
3. None ☐
4. Other specify …………………..

3. How many meters are the latrines located from the household?

………………………………………………………..

4. How is solid wastes managed within the household?

…………………………………………………………………………………………………

5. Are there stagnant water near the household?

1. Yes ☐
2. No ☐

6. What is the quality of water at the household?

1. Good ☐
2. Bad ☐
3. Other specify ……………..

6. What was the condition of the water storage container in terms of the type, size of mouth; whether covered or not and cleanliness?

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

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

s

Appendix 4: Health records collection form

Name of the Hospital: ………………………… Date of visit: ……………………

Name of clinician: ………………………….

What are some of the prevalent diseases in these areas for the past one year?

…………………………………………………………………………………………………

…………………………………………….

Table 4:1: Showing Incidences of water related diseases in the hospitals

Patients / Name of Disease	Children		Elderly (55- 70yrs)	Adults (18 – 54yrs)		Month of disease incidence
	Male(0-5 yrs)	Female 6 - 17yrs		Males	Females	

Appendix 5: Membrane Filtration techniques APHA 2005 methods

Analysis for Total coliforms, *E. coli, fecal streptococci* and *Salmonella species*.

Laboratory apparatus/ materials.

- Water sample
- 47-mm Petri plate containing Endo Agar
- 47-mm Petri plate containing Enterococcus agar
- Sterile membrane filter apparatus
- Sterile 0.45-µm filters (2)
- Blunt-tip forceps
- Alcohol
- Sterile pipette or graduated cylinder, as needed
- Sterile rinse water
- Dissecting microscope

Procedure

Preparing the membrane filter.

1. The membrane filtration equipment was set up and filter traps will be fitted into place to the vacuum source.
2. The filter holder base (with stopper*)* was attached on the filtering flask and to the filter trap.
3. The forceps was disinfected by dipping into alcohol and burning off the alcohol with the beaker of alcohol kept away from the flame.
4. Using the sterile forceps, a filter was placed on the filter holder.
5. The funnel was set on the filter holder, and fastened in place.

Filtering the sample

1. The water sample was shaken well to resuspend all material, and was poured or pipette a measured volume into the funnel. *(For samples of 10ml or less, pour 20ml of sterile water into the funnel first.)*
2. The vacuum was turned on to allow the sample to pass into the filtering flask. The vacuum was left on.
3. Sterile water was used to rinse the funnel. The funnel was rotated while pouring the sterile water to wash bacteria from the sides of the funnel. *(Use the same volume as the sample.)* The rinse water was allowed to go through the filter. The vacuum was turned off.

Inoculating the filter

1. Carefully the filter was removed from the filter holder using sterile forceps.
2. The filter was carefully placed on the Endo agar. The filter should not be bending; place one edge down first, then carefully set the remainder down. Air spaces should not be left between the filter and agar. Place the filter on the agar as it was in the filter holder.
3. The plates was inverted and incubated for 24 hours at 44.5°C for *E. coli* and 48hrs at 45^0C for total coliforms.
4. Steps 1, 2, and 3 was repeated using the same water source. The filter was placed on *Streptococcus* agar. The plates will be inverted and incubated for 48 hours at35°C.
5. Endo plate was examined using a dissecting microscope. On Endo agar, coliforms will form red colonies with a green metallic sheen. Plates with 20to 80coliform colonies was counted and not more than 200colonies of all types.
6. The *Streptococcus* plate was examined using a dissecting microscope. On *Streptococcus* agar, *Streptococcus* formed red colonies. Plates with 20to 60*Streptococcus* colonies and not more than 200colonies of all types was counted.
7. The bacteria in the original water sample was calculated.

Calculation of coliform density

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

Identification of *Fecal streptococcus, E.coli, Salmonella species.*

Required

- Growth media-*Salmonella shigella* agar, Chromocult media-Total coliform and *E.coli* . M-enterococcus agar.
- Water sample.
- Petri dish.
- Membrane filter (0.45µm pore size).

Procedure

1. The sample was filtered through a sterile 142mm diameter membrane of 0.45µm pore size.
2. For turbid waters, the filter was pre-coated;1 liter of sterile diatomaceous earth suspension (5g/L reagent grade water and filter about 500ml) was made.

3. After filtration, membrane was placed in a sterile blender jar containing 100ml sterile o.1% peptone water and peptone water and homogenize at high speed for 1minute.
4. The entire homogenate was added to 100ml double strength selective enrichment medium.
5. It was incubated for 24hours at 35-37^{o}C for *Salmonella shigella* agar.
6. It was observed and colony count was performed.

Appendix 6: Nacosti Research Permit

NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

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

Ref: No.

Date:

27th August, 2015

NACOSTI/P/15/0999/7318

Edith Jepchirchir Kurui
Egerton University
P.O Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Prevalence of water related diseases in relation to microbiological water quality of water pans in Central and South Baringo, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Baringo County** for a period ending **25th March, 2016.**

You are advised to report to **the County Commissioner and the County Director of Education, Baringo 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.

SAID HUSSEIN
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Baringo County.

The County Director of Education
Baringo County.