DETERMINATION OF FECAL CONTAMINATION STATUS OF SHALLOW WELLS IN DEDE DIVISION, MIGORI COUNTY, KENYA

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THESIS SUBMITTED IN PARTIAL FULFULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (ENVIRONMENTAL HEALTH) IN THE SCHOOL OF PUBLIC HEALTH OF KENYATTA UNIVERSITY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other instituition.

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DEDICATION

With lots of appreciation for their patience, understanding and love. I dedicate this to my fiancee, my Mum and Dad who always encouraged me, nourished my soul and empowered my spirit.

God Bless You.

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I express my deep sense of gratitude to the almighty God for wisdom, knowledge, the priviledge of good health and perseverance until successful completion of the study. I gratefully acknowledge my very able supervisors Dr. Daniel Akunga and Dr. Jackim Nyamari who made great professional contributions towards the success of this thesis, their guidance, timely feedback and overwhelming support during the study period. Gratitudes to my family members Michael, Philip, Fredrick and Monica for their moral support and prayers during the entire study period. I am also very thankful to my fiance Mitchelle, all my friends for providing constant encouragement, support and valuable suggestions. Finally, I would like to register my appreciation to the heads of households in Dede Division for their valuable time, resources and unbelievable willingness to participate in the study. I sincerely cherish you all and may God richly bless you.

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ABBREVIATIONS AND ACRONYMS

CFU	- Colony Forming Unit.
CHSIP	- County Health Strategic Information Plan.
DHIS	- Demographic Health Information System.
DNA	- Deoxyribonucleic Acid.
E-Coli	- Escherichia coli.
GLAAS	- Global Analysis and Assessment of Sanitation.
GWQ	- Guidelines for water quality.
HIV and AIDS	- Human immune deficiency virus and Acute Immuno-Deficiency Syndrome.
KIWASCO	- Kisumu Water and Sewerage Company.
MFT	- Membrane Filter Technique.
MoH	- Ministry of Health.
MPN	- Most Probable Number.
MSD	- Minimim Safe Distance
PCR	-The polymerase chain reaction.
UNEP	- United Nations Environmental Agency.
UNICEF	- United Nations Children's Fund.
WASH	- Water Sanitation and Hygiene.
WHO	- World Health Organization

OPERATIONAL DEFINITION OF TERMS

Excreta-related Disease: A disease spread through direct or indirect contact with fecal viruses, bacteria, and parasites.

Head of Household: An individual in one family setting who provides for other members.

House-hold: A house and its occupants, within which food preparation takes place.

Human Determinants: Level of knowledge of households on fecal contamination routes, human hygiene and sanitation practices and economic status of heads of households.

Hygiene: Those behaviors or practices that can affect the health of an individual or others positively or negatively.

Sanitation: The physical infrastructure that enables people to practice hygienic behaviors.

Sanitation-related Disease: Any illness that is transmitted by people who lack both the sanitary facilities for waste disposal and the knowledge needed to dispose of wastes in a sanitary manner.

Shallow Well: A water well that is dug, bored or drilled not more than 50 meters deep into the ground.

Technical Determinants: Siting/location, gradient, distance of shallow wells in relation to pit latrines and shallow well protection status.

Water Hygiene: protecting water from contamination and ensuring its safety right from the source to the stomach.

Waterborne Disease: Any Illness caused by drinking water contaminated by human or animal feces, which contain pathogenic microorganisms.

ABSTRACT

A shallow well is a hole dug, bored or drilled less than 50M deep to extract water. Contamination of shallow wells with fecal matter presents a grave public health threat in developing countries, such as Kenya, where large numbers of households lack access to clean and safe water supplies and rely on untreated surface water sources or shallow unprotected groundwater for domestic utilization. A report by WHO shows that 1 billion people practice open defecation with nine out of ten of them in rural areas and it is estimated that 1.8 billion people use a source of drinking water that is fecally contaminated. In Kenya unsafe water, sanitation and hygiene are the 2nd leading risk factors causing morbidity and mortality at the national and county levels respectively. In Dede Division, 65.5% of households depend on shallow wells for domestic needs and there are rising trends of confirmed cases of fecal-related diseases. The study sought to assess human and technical determinants of fecal contamination status of shallow wells in Dede Division. A cross-sectional study of households using the wells was conducted. Fisher's formula was then used to calculate the sample size of the heads of households. Since the approximated number of households using shallow wells was <10,000 (4008), the two stages of the formula were adopted, giving a sample size of 386 heads of households. Out of the 180 shallow wells, 54 (30% of 180) were proportionately sampled and grab sampling technique adopted while sampling water from each of the sampled shallow wells. Basic physical parameters like temperature, turbidity and pH were analysed by a portable turbidity meter and pH meter while H_2S rapid field test was employed for total corliforms analysis of grab samples in the field. Fecal contamination status of each well was determined by Membrane Filter Technique in kisumu government labaratory. Chi-square test was used to measure associations between variables while Multi-variate logistic regression analysis applied to test the hypotheses. The study reported significant relationship between level of knowledge of respondents on a well being too close to a latrine as a potential route (risk factor), a well located downhill a latrine, an open/uncovered well, surface run-offs into wells, dropping objects in shallow wells, using a dirty drawer, people/animals dropping in wells, doing laundry next to a well, and human/animal feces dropping in the well as potential routes of fecal contamination. It further revealed significant associations between several technical determinants and fecal contamination status of shallow wells e.g distance (M) from a latrine to a well, with majority of wells within safe distances of contamination (>10M) but still tested positive for fecal corliforms, distance (M) from the nearest cattle pen if any with a significant majority of shallow wells testing positive for fecal corliforms, damage or lack of concrete plinth, breaks/cracks on the parapet walls, breaks/cracks in the cover/top slab, breaks in the drainage channels, shallow well covered while not in use and shallow well fenced out respectively. Majority of shallow wells (69%) tested positive for *E. Coli*, a strong indicator for presence of fecal matter in water, with only 31% testing negative. Common human and technical determinants (risk factors) by and large are functions of fecal contamination status of shallow wells in Dede Division. Efficient protection of shallow wells is a critical pointer to their ground water quality. Households in Dede Division should ensure adequate treatment of shallow wells for fecal contamination before utilization of water from these sources. This can be both at source or household level. They should be sensitized by the relevant authorities on common routes of fecal contamination of shallow well water and safe hygiene and sanitation practices around shallow wells to prevent fecal contamination of the wells. Households using shallow wells in Dede Division should ensure proper sighting and location of latrines in relation to shallow wells to avoid fecal contamination of the wells through leaching. The pit latrines should be sighted down hill the shallow wells and located atleast 10 meters apart.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

A water well is a hole dug, bored or drilled into the ground to extract water for domestic consumption. It is considered shallow if less than 50 meters deep (King, 2014). Fecal contamination of water from a health point of view is the pollution of water with pathogens that may inhabit the small and large intestines of human beings. Ingestion of water contaminated with feces is responsible for a variety of diseases important to humans via the fecal-oral route of transmission. In 1998, it was approximated that 2.2 million deaths were connected to diarrhea each year, and a significant percentage of them due to fecal contamination of water, with the vast majority of victims being children in rural areas of the poor countries.It has also been estimated that more than 1 billion people worldwide do not have adequate access to safe drinking water, and more than 2 billion people do not have sufficient access to sanitation facilities (WHO, 2009).

A World Health Organization analysis and report on Global Analysis and Assessment of Sanitation and drinking water shows that 2.5 billion people do not have adequate access to improved sanitation, 1 billion people practice open defecation with nine out of ten in rural areas. 748 million people lack access to improved drinking water, and it is estimated that 1.8 billion people use a contaminated source of drinking water that is faecally contaminated (WHO, 2014). Poor hygiene, sanitation, and water exacerbate poverty levels by reducing productivity and elevating health-care costs (UNICEF, 2006).

Moreover, problems linked to fecal contamination of water are likely to increase with time, as both rural and urban populations continue to rise, with the generation of human and animal wastes skyrocketing. Contamination of underground water sources with fecal matter presents a grave public health threat in developing countries, such as Kenya, where large numbers of households lack access to clean and safe water supplies and rely on untreated surface water sources or shallow unprotected groundwater for domestic utilization (WHO, 2009).

Controlling and managing fecal pollution can be exceedingly challenging for developing countries like Kenya due to scarcity of public resources, widespread poverty, high infectious disease burden, and unreliable and inadequate information about the extent, nature, sources and risks of fecal pollution (Sivaborvorn and Dutka, 2009). Another study shows that over 2.8 million cases of cholera worldwide were recorded by the World Health Organization from 2001–2011, including almost 50 000 deaths. The incidence stands at 2.0 cases per 1000 people at risk (Loharika *et al.*, 2013).

Approximately 66.0% of global cholera cases and 87.6% of fatalities occur in Sub-Saharan Africa. Cholera kills an estimated 91,000 people annually; the mortality rate varies from 0.1 per 100,000 in developed countries to 15.2 per 100,000 in Africa. A report by World Health Organization outlines that cholera case fatality rates should not exceed 1% if cases are properly treated. However, the outbreaks have continued to kill greater than one percent of the cases. In 2010, for instance, 46% of countries, which reported cholera outbreaks, had case fatality rates exceeding the World Health Organization recommended level (WHO, 2013).

Diarrheal diseases are the fifth leading cause of morbidity and mortality in children under five years nationally and the third and second leading cause of morbidity and mortality in children under five years at the county levels respectively (DHIS, 2012).

This could be largely due to consumption of unsafe water, especially in the rural areas. This is coupled with the high prevalence of HIV/AIDS which renders quite some county residents immune-compromised has significantly increased their vulnerability.

1.2 Statement of the Problem

Contamination of underground water sources with fecal matter presents a grave public health threat in developing countries, such as Kenya, where large numbers of households lack access to clean and safe water supplies and rely on untreated surface water sources or shallow unprotected groundwater for domestic utilization (WHO & UNICEF, 2009). A report by the WHO on Global Analysis and Assessment of Sanitation and Drinking water shows that 1 billion people practice open defecation with nine out of ten of them in rural areas,and it is estimated that 1.8 billion people use a source of drinking water that is fecal contaminated (WHO, 2014). Due to high population growth and improper fecal waste disposal, there has been an increase in the prevalence of water-borne diseases, especially diarrheal diseases (WHO, 2009). In Kenya unsafe water, sanitation and hygiene are the second leading risk factor causing morbidity and mortality at the national and county levels respectively (CHSIP, 2013-2017). In addition, diarrheal diseases are the fifth leading cause of morbidity and mortality in children under five years nationally and the third and 2nd leading cause of morbidity and mortality in children under five years at the county levels respectively (DHIS, 2012). In Dede Division, there have been rising trends of confirmed cases of fecal-related diseases for the last four years (DHIS, 2014), Awendo Sub-county.

In March 2015 alone, there were 62 confirmed cases of cholera in Dede Division, which gives an average of 2 new cases per day (DHIS, 2014) in Awendo Sub-county.

This study therefore, sought to assess determinants of fecal contamination status of shallow wells, together with knowledge, practices and perceptions that influence shallow well water quality in Dede Division, Migori county. If nothing is done to address this problem adequately, it may worsen in the coming decades as rural populations continue to increase, and wells remain a significant source of domestic water consumption.

1.3 General Objective of the Study

To assess determinants of fecal contamination status of shallow wells by households in Dede Division, Migori County, Kenya as a first measure in reducing or eradicating fecal-related disease burden in the area.

1.3.1 Specific Objectives

i. To determine fecal contamination status of shallow wells in Dede Division.

ii. To assess human determinants of fecal contamination status of shallow-wells in Dede division.

iii. To ascertain technical determinants of fecal contamination status of shallow wells in Dede Division.

1.4 Research Questions

i. What is the fecal contamination status of shallow wells in Dede Division?

ii. What are the human determinants of fecal contamination status of shallow wells in Dede Division?

iii. What are the technical determinants of fecal contamination status of shallow wells in Dede Division?

1.5 Hypotheses

i. Human determinants are not a function of fecal contamination status of shallow wells within Dede Division.

ii. Technical Determinants are not a function of fecal contamination status of shallow wells in Dede Division.

1.6 Justification of the Study

Over 40% of Kenyans still drink fecally contaminated water resulting into high incidences of diarrheal diseases, (Mahler *et.al,* 2011). Latest estimates show that only 82% of urban and 52% of rural Kenyan populations have access to improved water sources, with only 32% of both urban and rural populations having access to improved sanitation (Mutonga *et al.,* 2013).

In Dede Division, a significant majority of households at 65.5%, rely on shallow wells for their domestic water needs (MOH, 2014), Awendo Sub-county. Whether this increase is a function of the quality of shallow well water is not documented since the quality of shallow well waters in this Division has not been established. Very little advancements have been made to address and end these problems in developing countries like Kenya, particularly due to the rapidly increasing rural and urban populations.

1.7 Significance of the Study

Upon completion of the study, its findings may be vital in coming up with the most efficient and adequate intervention measures of reducing fecal contaminations of shallow well waters hence significantly reduce or eliminate continued incidences of morbidity and mortalities resulting from fecal-related diseases. The findings may also help come up with effective recommendations for well water protection and sitting about latrines and waste disposal sites. This may significantly reduce or eliminate reoccurrence of fecal-related diseases and by extension reduction in communicable disease burden within the Division. The study may also be beneficial to the government through the Ministry of Health by informing policy formulation on issues of sanitation and safe hygiene practices that may ultimately help reduce fecal contamination of wells and new cases of excreta-related and sanitation-related diseases. Through health education, households may also learn safe waste management practices that would eventually improve their quality of life.

1.8 Delimitation and Limitation

The study was conducted within Dede Division on shallow wells and among household heads strictly within the Division. Due to the vastness of the study area, and the expensive nature of standard procedures for well water sampling, packaging, transportation and testing, sampling of both shallow wells and household heads was challenging. This resulted in sampling error that was minimised by adopting the most appropriate sampling techniques that ensured equal chance of inclusion in the study. In addition, the study ensured that any biases in responses by the heads of house holds were minimized through voluntary participation.

1.9 Assumption

The main type of soil is loam in Dede division.

1.10 Conceptual Framework

Figure 1.1 below, illustrates how human determinants e.g knowledge of household members on common fecal contamination routes of shallow wells, their hygiene/sanitation practices and economic status may influence presence or absence of fecal matter in shallow wells. It further demonstrates how technical determinats e.g siting /location in relation to pit latrines, topography/slope, distance from shallow wells to pit latrines and well protection may determine wether there is presence or absence of fecal matter in the respective shallow wells.

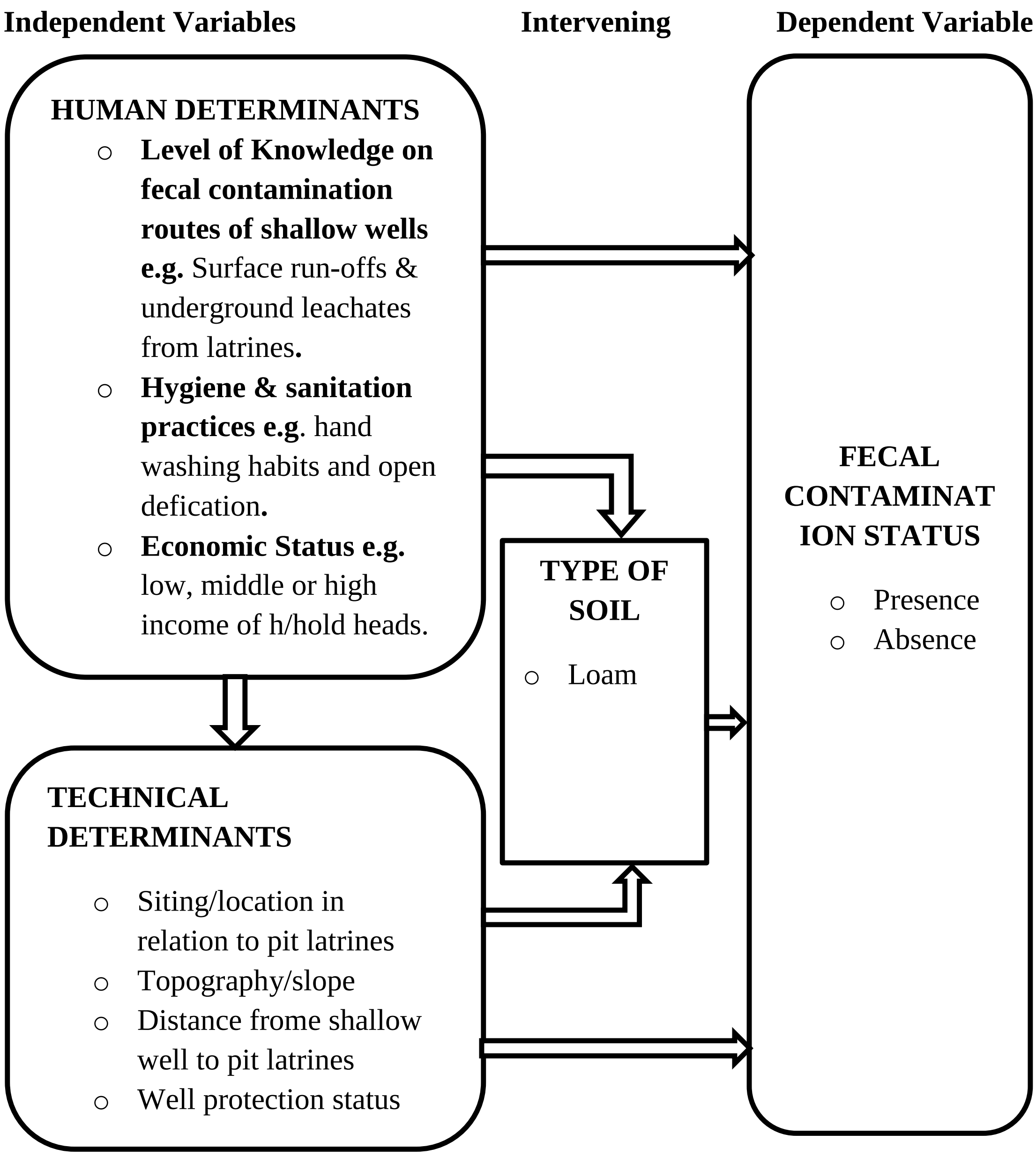

Figure 1.1: Conceptual Frame-work

The levels of knowledge of Dede Division residents on fecal contamination routes of wells e.g. Leachate from latrines flowing through open underground cracks into wells, surface run-offs sweeping both human and animal wastes from open fields into unprotected shallow wells and leakage from sewer lines may influence their sanitation practices and hygiene habits such as open defecation, cattle dropping disposal habits, latrine siting in relation to wells among others. These may consequently predict the presence or absence of fecal matter in shallow well waters.

Open defecation, for instance, is a practice that may lead to comtamination of soil by feces, which further may lead to fecal contamination of shallow well waters through leaching. The rate of leaching into the shallow well may depend on the type of soil upon which the shallow well is dug.

Siting and location of shallow wells visa-vi pit latrines and animal waste diposal sites may influence fecal contamination status of shallow wells. The shorter the distance, the higher the risk of fecal contamination. This may also be dependent on the geological nature of the area i.e., type of soil, ground water table level e.t.c. These are independent of the human activities and habits on the surface that may also enhance amenability of shallow wells being fecally contaminated.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of the literature on determinants of fecal contamination status of wells; it comprises of theoretical and critical literature review of the study to be addressed.

2.2 Review of Theoretical Literature

Water intended for consumption whether from a shallow well or a cased well must be of good quality and meet the acceptable standards set out in the *Regulation respecting the quality of water for drinking and domestic use (*Conboy &Goss, 2010). While well water may appear to be clear and pure, and have no specific odor or taste, it may contain elements that can have undesirable effects on health, for example pathogenic micro-organisms (bacteria, viruses, or protozoa). Ground water, which is generally of better quality than surface water (lakes, rivers, streams) owing to the soil's natural filtering capacity, may be vulnerable to contamination, and precautions must be taken to treat adequately the source before consumption of the water (WHO, 2010). A study by UNEP, (2008) recommends that well water be tested at least twice a year, namely in the rainy season and dry season. Additional tests should be performed if you notice sudden changes in the water's taste, odor, appearance, or if changes have been made to the well or surrounding soil. In addition to the recommended tests, you must check the condition of the well and septic facilities, examine possible sources of contamination in the environment around the well, and take remedial action (Gerhard *et.al*, 2010).

2.2.1 Coliforms

Coliforms are a broad class of bacteria found in our environment, including the feces of man and other warm-blooded animals.The presence of Fecal Coliform bacteria or *E. coli* indicates contamination of water with fecal waste that may contain other harmful or disease-causing organisms, including bacteria, viruses, or parasites such as *Giardia*, the cause of beaver fever. Drinking water contaminated with these organisms can cause stomach and intestinal illness including diarrhea and nausea, and even lead to death. These effects may be more severe and possibly life-threatening for babies, children, the elderly or people with immune deficiencies or other illnesses (WHO, 2010). Coliforms include all aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli that, when incubated at 35^0c, can ferment lactose and produce gas (CO_2) within 48 hours. They are cultured by increasing the incubation temperature to 44.5^0c (WHO, 2010).

2.2.2 Testing Fecal Contamination in Water

When water is tested for Fecal or Total Coliform, the results are usually given as the number of colony forming units per 100 milliliters (CFU/100ml) of water sampled. No sample should contain Fecal Coliform or *E. coli*, and ideally there should be no Total Coliform. However, a single sample may contain up to 10 Total Coliform CFU/100 ml (Sivaborvorn & Dutka, 2009). The presence of algal growth in water sources is the simplest way of suspecting fecal contamination, particularly in surface waters. He further recommends that such water is pathogenic, and should not be consumed at all without adequate treatment (Olivieri, 2011). Bacteria that are found in water are measured in CFU's. A CFU is a "colony forming unit." They are given this name based on the laboratory testing methods used for counting bacteria such as Coliform. A water sample is shaken, and then a small amount of this water is plated on a bacterial growth media. The plate is then incubated at a temperature of 32^{o}c and after about a day any bacteria present will have multiplied forming a small colony that appears as a dot. The colonies is counted, and this results in the bacterial "count" which is reported (WHO, 2010).

Here, a minimum volume of 10ml of the sample (or dilution of the sample) is introduced aseptically into a sterile or properly disinfected filtration assembly containing a sterile membrane filter (nominal pore size 0.2 or 0.45mm). A vacuum is applied, and the sample is drawn through the membrane filter (WHO, 2006). All indicator organisms are retained on or within the filter, which is then transferred to a suitable selective culture medium in a Petri dish. Following a period of resuscitation, during which the bacteria become acclimatized to the new conditions, the Petri dish is transferred to an incubator at the appropriate selective temperature where it is incubated for a suitable time to allow the replication of the indicator organisms (WHO, 2006).Visually identifiable colonies are formed and counted, and the results are expressed in numbers of “colony forming units” (CFU) per 100ml of original sample. This technique is inappropriate for waters with a level of turbidity that would cause the filter to become blocked before an adequate volume of water had passed through. When it is necessary to process low sample volumes (less than 10ml), adequate volume of sterile diluent must be used to disperse the sample before filtration and ensure that it passes evenly across the entire surface of the membrane filter. Membrane filters may be expensive in some countries (WHO, 2004). It is faster to prepare than many other traditional methods and is one of the few procedures that will allow the isolation and enumeration of microorganisms. It has several advantages e.g. Permits testing of large sample volumes, Reduces preparation time as compared to many traditional methods, allows isolation and enumeration of discrete colonies of bacteria and Provides presence or absence information after incubation within 24-48 hours. It is an **e**ffective and acceptable technique used to monitor drinking water quality standards in government laboratories (EPA, 2012). Municipal water treatment plants monitor drinking, waste, and surface water for the presence of coliform bacteria by the MF Technique, with the key organism being *E. coli* (EPA, 2012).

The multiple-tube (MTM) method is also referred to as the most probable number (MPN) method because, unlike the MFT method, it is based on an indirect assessment of microbial density in the water sample by reference to statistical tables to determine the most probable number of micro-organisms present in the original sample. It is essential for highly turbid samples that cannot be analysed by membrane filtration. The technique is used extensively for drinking-water analysis, but it is time-consuming to perform and requires more equipment, glassware, and consumables than membrane filtration. However, the multiple tube method may be more sensitive than membrane filtration (WHO, 2010).

Presence–absence tests may be appropriate for monitoring drinking water quality where positive results are rare. They are not quantitative and as their name suggests, they indicate only the presence or absence of the indicator sought. Such results are of very little use in countries or situations where contamination is common; the purpose of analysis is then to determine the degree of contamination rather than indicate whether or not contamination is present (WHO, 1997).

2.3 Human Determinats of Fecal Contamination Status of Shallow Wells

2.3.1 Knowledge on Fecal Contamination Routes

Water is essential for survival and is the major mode of transmission of cholera. Cholera is prevented by stopping its contamination cycle, which begins when a person ingests water, or food that is contaminated with fecal matter or infected with *Vibriocholerae* (Loharika*et al.*, 2013). Water quality parameters that indicate the interaction of leachate from the latrine, other contaminants and ground water are fecal coliforms, nitrates, and phosphates. Fecal contamination of water is a major problem for human health and has led to some major waterborne disease outbreaks (Mackenzie *et.al*, 2009). Well water can be highly susceptible to fecal contaminants, with pathogens frequently observed in them if tested (Lemarchand & Lebanon, 2010). Bacterial pathogens are present in human and animal feces, which can in turn contaminate well water. Fecal contamination can reach ground water sources, including drinking water wells, from failed septic systems, leaking sewer lines, by passing through the soil and large cracks in the ground. Domestic pets, especially dogs, and cats can contribute to fecal contamination of well waters. Runoff from roads, parking lots, and yards can carry animal wastes to unprotected wells through erosion (Dighton, 2010).

Barnes and Gordon, (2008) document that one of the most frequent types of contamination in rural areas is fecal pollution from different sources, most frequently livestock and inadequate on-site human waste disposal systems which are poorly sited and installed in close proximity to wells. One of the difficulties in tackling this problem is the fact that contamination is likely to come from various possible point and non-point sources (Mahler *et. al*, 2010). Many people in the rural areas lack the basic hygiene knowledge for safe water handling. The knowledge a person has on water safety and hygiene and susceptibility of the person exposed is very critical in the severity of the water-borne diseases experienced in rural areas. The short-term effects of exposure to fecal pathogens tends to be a greater problem for immune-compromised and immune-suppressed people, like infants, the aging, and those experiencing debilitating illnesses (e.g., pneumonia and AIDS), a majority of who are found in the rural areas (Townsend, 2009). There are gaps in knowledge on possible fecal contamination routes of shallow wells in partucular.

2.3.2 Hygiene and Sanitation Practices Linked to Fecal Contamination of Wells

Human activities are the core contributors of up to 85% of fecal water pollution. The major culprit emanates from poor positioning of pit latrines particularly in rural areas and slums (Donderski & Wilk, 2008). Improper personal and environmental hygiene practices mostly dominant in the developing countries have also elevated fecal contamination of well waters over the past decades (Conboy & Goss, 2009). Many people handle fecal wastes particularly from children and the disabled people around water sources for convenience as a result contaminating the water with feces. Poor well maintenance and construction (particularly shallow dug wells) can also increase the risk of bacteria and other harmful organisms getting into a well water supply. Improper handling of urban and industrial waste water or agricultural run-off water by the authorities concerned has given rise to long-term exposure to pollutants, which can have a range of serious health implications (WHO, 2010). Ground water sources get in touch with E, Coli from the waste waters through seepage or infiltration especially in the urban set-ups where these services are dominant. This compromises the safety and quality of ground water putting the consumers at risk of water-borne diseases (WHO, 2010). However there are glaring gaps in literature on other specific sanitary practices as outlined by the world health organization standards.

2.4 Technical Determinats

2.4.1 Siting of Water Wells

Shallow ground water movement reflects surface topography; sources of contamination should therefore be located downhill of drinking-water sources wherever possible. When abstraction from a water source for human consumption is being considered, the minimum safe distance (MSD) for all potentially polluting activities should be fixed during the planning stage (WHO, 1997). The MSD should be determined from the time taken by contaminants to travel from their source to the source of drinking-water. This will depend on local conditions, the most important of which are the geological and hydrogeological conditions of the area, the quantity of faecal matter likely to be discharged, and the number of existing and planned sources of contamination (WHO, 1997). A pit latrine should be sited/located a minimum distance of 30M from a well or a water source and more than 10M away from a dueling area (AMREF, 2001). Majority of investors don't adhere to the recommended distance between the water sources and latrines subsequently facilitating well water contamination through underground seepage of the pathogenic coliforms (Fong *et.al,* 2007).

2.4.2 Geology

Water well siting in hard rock areas is impared by the high uncertainity of hydrogeological conditions (Sander, 1997). Many Kenyans use wells to obtain domestic water and also use pit latrines that are often close in distance to the wells. This causes contamination of the wells because the micro-organisms travel from the pit latrines to the wells. The wells should be placed in elevated areas (at least 2M above the water table) and at least 15M from pit latrines, which however is not the case in most over crowded rural areas and urban slums (Marshall, 2011).

2.4.3 Catchment and Ground Protection of Water Wells

The sides of a water well should be lined with impervious material to the depth of about 3M, and incase of deep wells upto the 1st impervious stratium. The top should be covered by a concrete apron which drains away from the entrance of the well

(Obura & Mwanthi, 2014). A drain should be provided around the apron to drain spilled water away from the well. The method of water extraction should be improved and where possible a pump should be used (Obura & Mwanthi, 2014). A hand dug shallow well is about one to two meters in diameter (WHO, 1997). Open or poorly covered well heads pose the commonest risk to well-water quality, since the water may then be contaminated by the use of inappropriate water-lifting devices by consumers (WHO, 1997).

CHAPTER THREEE: METHODOLOGY

3.1 Introduction

This chapter presents the methodology of the study, and it entails the research design, study population, data collection, data analysis and ethical considerations.

3.2 Study Design

The study employed a cross-sectional study design since relevant responses from heads of households and well water samples were collected at one specific point in time and no interventions or follow-ups conducted after completion of the study. Analytical Design was then applied where water samples collected from the sampled shallow wells were transported to a standard government laboratory for bacteriological (fecal corliform) analysis.

3.3 Variables

The study was conceptualized as per the variables outlined below:

Independent Variables

Human Determinants e.g., Level of knowledge of households on fecal contamination routes and hygiene and sanitation practices by households i.e, surface runoffs, hand-washing practices at the wells, open defecation and other onsite sanitation practices around shallow wells; farming practices, level of education e.t.c. Level of knowledge was measured using a four point lichart scale with respondents either strongly agreeing, agreeing, disagreeing and strongly disagreeing. Sanitary practices around wells were measured using a sanitary risk assessment of shallow wells checklist modified from WHO water quality standards (WHO, 1997).

Technical Determinats e.g., siting, distance from the nearest pit latrine, gradient of shallow wells visa-vi pit latrines and animal waste disposal sites and any other sanitary risks of contamination around the wells.

Dependent Variable

Fecal contamination status of shallow well waters i.e, presence or absence of fecal corliforms.

3.4 Location of the Study

The study was conducted within Dede Division which covers a total of 108.30 square Kilometers. It is divided into West-Sakwa and North-Sakwa Wards respectively, with a total population of about 45,152 people (Census, 2009). It is located in the sugar belt wetlands of western and is bi and large experiencing tropical climate. The Division enjoys a pleasant climate due to high altitudes and the cooling breeze from lake Victoria. The main economic activity of the area is sugarcane farming which is supported by the vast loam soil in the region. This division was most appropriate for the study because it had the highest confirmed prevalence of waterborne and excreta-related diseases of the two divisions within Awendo Sub-county and the highest number of wells at 82.02% as compared to other water sources (MOH, 2014), Awendo sub-county.

3.5 Study Population

Households using shallow wells and wells within Dede Division.

3.5.1 Target Population

Heads of households using shallow wells as a source of water for domestic use and shallow wells within Dede Division. There was a total of 180 shallow (hand dug) wells and approximately 4008 households using wells respectively in Dede Division (MoH, 2014), Awendo Sub-county.

Inclusion Criteria

- All household heads whose households depend on shallow wells as a source of water for domestic consumption, sampled and were willing to participate in the study.
- All shallow wells within dede division which were sampled in the study.

Exclusion Criteria

- All household heads whose households depend on shallow wells as a source of water for domestic consumption, sampled and were not willing to participate in the study.
- All household heads whose households do not depend on shallow wells as a source of water for domestic consumption.

3.6 Sampling Techniques

3.6.1 Households and Shallow Wells

Cluster sampling was employed to divide the Sub-County into two wards namely: North-Sakwa and West-Sakwa respectively. The wards were then further Clustered into sub-locations namely; South-Kanyamgony, North-Kanyamgony, Rabondo, Kamresi, Kadera-Kwoyo, Kadera-Lwala, East-Kakmesia, Kanyasrega, and West Kakmesia respectively (see table 3.1).

3.6.2 Shallow Well Water Sampling Technique

Grab water sampling technique was adopted. Grab samples were collected from each selected shallow well using a standard 500ml sterelised sample collection bottle following the standard shallow well water sampling procedure as outlined in the World health Organization drinking water quality Standards (1997), details are presented in appendix VII.

3.6.3 Transportation of Grab Samples

Although recommendations vary, the time between sample collection and analysis should, in general, not exceed 6 hours and 24 hours is considered the absolute maximum (WHO, 2010). The grab samples were therefore transported within 6 hours, in a light-proof insulated box with melting ice or ice parks with water to ensure rapid cooling to KIWASCO government laboratory in Kisumu for further bacteriological (fecal corliforms) analysis.

3.7 Sample Size Determination

3.7.1 Households Using Shallow Wells

Fisher *et al.,* (1998) formula was used to calculate the sample size of households to be sampled. Since the number of households using shallow wells was less than 10,000 (4008), the two stages of the formula was adopted. The first part of the formula was used with an assumption of a population of more than 10000 to enable the researcher to get the value of "n" which then were used in the second part of the formula to calculate "fn" which represented the desired sample size when the target population is less than 10000 as illustrated below:

$n=Z^2pqD/d^2$

Where:

n= is the desired sample size when the study target population is over 10,000

Z= the standard normal deviate, usually set at =1.96 (@ 95% confidence level).

P= The current propotion of wells fecally contaminated in Kenya (0.5).

q= I–P = 0.5

D=Study design effect (usually 1 when it is not a comparison study)

d = is the Degree of Accuracy required (0.05)

$n = Z^2pqD/d^2 = [1.96^2 \text{ x } 0.5\text{x}0.5\text{x}1]/ [(0.05)^2 = 384.16 = 384$ House Holds.

However,

The target population is less than 10,000, and therefore we use:

$$nf = \frac{n}{1 + (\frac{n}{N})}$$

Where:

nf=The desired sample size when population is less than 10,000

n = the desired sample size when the population is more than 10,000

N = the estimate of the population size.

nf ={384}/{1+(384/4008)}= 350.559= 351 Household Heads.

Attrition Rate =10% of 351=35Household Heads.

Total Sample Size 351+35 =386 Household Heads.

Therefore, 386 household heads were sampled and issued with self-administered questionnaires.

3.7.2 Shallow Wells

A study sample size should be as large as possible so as to produce the salient characteristics of the target population to an acceptable degree, with 30% of the total population recommended as the minimum sample size for descriptive studies, Mugenda & Mugenda, (2008). Out of the 180 shallow wells, 54 (30% of 180) were proportionately sampled for water sampling (see table 3.1 below).

Table 3.1: Sampling Frame of Shallow Wells and Households in Dede Division

Sub-Location	No. of Wells	Sample Size of wells in @ Sub-location	N/n	No. of H/holds using wells	Sample Size of H/holds in @ Sub-location	N/n
South Kanyamgony	25	{25/180}*54=**8**	3	544	{544/4008}*386=**52**	10
Rabondo	20	{20/180}*54=**6**	3	381	{381/4008}*386=**37**	10
North Kanyamgony	31	{31/180}*54=**9**	3	596	{596/4008}*386=**57**	10
Kamresi	21	{21/180}*54=**6**	4	543	{543/4008}*386=**52**	10
KaderaKwoyo	25	{25/180}*54=**8**	3	472	{472/4008}*386=**45**	10
KaderaLwala	25	{25/180}*54=**8**	3	475	{475/4008}*386=**46**	10
East Kakmesia	10	{10/180}*54=**3**	3	379	{379/4008}*386=**37**	10
West Kakmesia	7	{7/180}*54 =**2**	4	319	{319/4008}*386=**31**	10
Kanyasrega	16	{16/180}*54=**5**	3	299	{299/4008}*386=**29**	10
Totals	**180**	**---**		**4008**	**---**	
Sample Size	**54**	**54**		**386**	**386**	

The sampled households (386) and shallow wells (54) were then proportionately distributed in each sub-location. Finally, systematic sampling was employed using appropriate intervals (N/n) as shown in the table above to help pick and mark the wells whose water was sampled and the respective household heads whose household members use the marked shallow well.

3.8 Research Instruments

3.8.1 Self-administered Questionnaire

A self-administered questionnaire was developed and issued to the respective heads of households for responses on human determinants of fecal contamination of wells e.g. their level of knowledge on common routes of fecal contamination of shallow wells, hygiene and sanitation practices, level of education and economic activities as outlined in appendix II.

3.8.2 A Checklist

A checklist was developed to help assess technical determinats i.e, observable sanitary risks around the wells, well protection status by checking different construction elememts like breaks/cracks in the drainage channels, parapet walls and in the cover top slab if any. Siting/location and topography in relation to sanitary facitlities e.g. latrines was examined by checking the positioning of shallow wells whether uphil, downhill or relatively on a flat ground visa-vis latrines and animal waste sites-cattle pens. Finally, the distance between shallow wells and the nearest latrines and cattle pens was determined by a tape meassure and the results noted.

3.8.3 Water Sample Collection Form

A model water sample collection form (WHO, 1997) was adopted and used to record collected grab samples results both physical (temperature and tubidity) in the field and bacteriological (*E. coli*) at the laboratory. Some details included, sample collection time, well number, date of collection, sub-location of collection,date of analysis, and time of analysis. See details in appendix IV.

3.9 Pilot Study

The pilot study was conducted in Kabuoro Ward outside the actual study area. This helped guard against pre-empting the study by the actual respondents. In addition, 10% of the sample size of the heads of households was used in the pilot. This was 17 heads of households.

3.9.1 Validity

Validity is the extent to which a study instrument captures what it purports to measure (Cooper & Schindler, 2006). Validity of the questionnaire was ensured through asking relevant questions that helped answer the specific objectives of the study. The researcher also discussed the contents of the questionnaire and the checklist with experts (supervisors) before collecting data in order to enhance content validity. Research assistants were adequately trained before being allowed to participate in data collection in the study.

3.9.2 Reliability

Reliability refers to how consistent a research procedure or instrument is (Bryman, 2008). The study maintained a high level of reliability by ensuring that questions outlined in the self-administered questionnaire were constructed using simple language that was easy to understand by all potential respondents. Cronbach's alpha analysis was run on the piloted questionnaires with the aim of attaining an alpha level of 0.75 and above.

3.10 Data Collection Techniques

A self-administered questionnaire and a checklist was used to collect data from heads of households and personal observation respectively in the study. In addition, water samples were collected on standard 1000ml sterilized laboratory bottles and immediately placed in a light proof Insulated box containing melting ice or ice-packs with water to ensure rapid cooling.

3.11 Data Analysis

3.11.1 In Situ Meassurement of Physical Parameters

Basic physical parameters of the grab samples e.g. tempereture, pH, and tubidity were immediately determined in the field using a portable thermometers, pH meters and turbidity meters respectively (WHO, 2010) and results recorded immediately.

3.11.2 In Situ Meassument of Microbial Parameters

Hydrogen sulfide (H_2S) rapid field test was used to test for presence or absence of total coliforms in the grab samples, after which grab samples positive for total corliforms were safely transported to the laboratory for fecal corliform analysis.

3.11.3 Labaratory Analysis of Grab Samples

Membrane Filter Technique was adopted to test for *E. coli* presence in the grab samples initially identified as positive for total corliforms during the field analysis as described below:

With hand gloves on, the 1000ml sterilized bottle containing grab sample from the field was carefully openned; the pouring lip of the grab sample bottle was then flamed and 100ml of the grab sample measured into a sterilized calibrated test tube and held with a test tube rack; appropriate nutrient or culture medium (Lactose Agar with Tergitol 7) was then selected; the selected medium was then dispensed into a sterile Petri dish, evenly saturating the absorbent pad; the forceps then flamed once more and the membrane filter carefully removed from the sterile package; carefully placed into the sterilized funnel assembly and the pouring lip of the test tube containing 500ml of sampled water flamed; then sample poured into the funnel, allowing the 500ml water sample to drain completely through the filter (WHO, 1997). The forceps then was flamed after which the membrane filter carefully removed from the funnel; Placed into the prepared Petri dish. The funnel was then rinsed with distilled water and the above procedure carefully repeated for all labelled grab samples from the field; Incubation was done at 44^0c-44.5^0c for 24-48 hours (WHO, 1997). (***E. coli*** survives at this temperatures). Colonies were then counted (Yellow central halo in the medium under the membrane) under 10-15 X magnification, confirmed and results reported.

3.11.4 Data Management and Analysis

Data from the respondents and observations made by the researcher as per the checklist were managed by Statistical Package for Social Sciences (SPSS) version 20 and Microsoft Excel 2013 softwares. This involved data coding, data entry, data cleaning, data summarization and data organization. Descriptive statistics were employed in organizing and summarizing data sets of collected variables. Chi-square was used to test associations between variables and multiple linear logistic regression analysis used to test the hypotheses (Kothari, 2004).

3.12 Logistical and Ethical Considerations

Permission was obtained from the National Comission for Science Technology and Innovation (NACOSTI) to conduct the study. Ethical clearance was sought from Kenyatta University Research Ethics Committee for any ethical issues which may have risen during the study. There after, the County Government of Migori, Awendo sub-county public health office, and the chiefs in charge of Dede Division were informed of the intention of the study. Informed consent was then sought from the selected respondents (heads of house-holds) and the purpose of the study explained to them to encourage voluntary participation. Confidentiality of participants was ensured through coding of questionnaires.

CHAPTER FOUR: RESULTS

4.1 Introduction

This chapter outlines detailed data analysis and comprehensive report findings of the study. The findings are presented using tables, graphs and pie charts. Data analysis was based on the specific objectives and research questions of the study. A total of 386 respondents were sampled to participate in the study, out of which the response rate was 98.18% (n= 379).

Table 4.1: Descriptive Summary of Demographic Characteristics

DEMOGRAPHICS	***n***	***%***
Gender		
Male	191	50.4
Female	188	49.6
Total	***379***	***100***
Age Bracket in Years		
18-27	90	24.5
28-37	166	43.8
38>	119	31.4
Total	***375***	***99.7***
Level of Education		
Primary	228	59.6
Secondary	95	25.1
College/University	58	15.3
Total	***381***	***100***
Occupation		
Self-employed	161	42.5
Employed	67	17.7
Unemployed	151	39.8
Total	***379***	***100***
Religious Affiliation		
Christian	372	98.2
Muslim	5	1.3
Others	1	.5
Total	***378***	***100***

The findings of the study show that 50.4% (n=191) of the respondents were males with the rest being females at 49.6% (n=188). In terms of age, most respondents were youths aged between 28-37 years at 43.8.% (n=166), with the minority aged between 18-27 years 24.5% (n=90). A significant majority had primary level of education at 59.6% (n=228), with only 15.3% (n=58) having attained college and university level education. The discrepancies in the above totals was due to variations in responses by the respondents on different questions.

Table 4.2: Socio-Economic Status of Respondents

DEMOGRAPHICS	***n***	***%***
Main Economic Activity		
Crop Farming	272	71.8
Livestock Rearing	46	12.1
Both	56	14.8
Gold Dealer	4	1.1
Total	***378***	***99.8***
Type of Housing		
Grass thatched	38	10.1
Semi-permanent	303	79.9
Permanent	38	10.0
Total	***379***	***100***
Size of Household		
1-2	39	10.3
3-4	111	29.3
5-6	149	39.3
7>	80	21.1
Total	***379***	***100***
Ward		
West Sakwa	188	49.6
North Sakwa	191	50.4
Total	***379***	***100***

The results further indicate the main economic activity in Dede Division is crop farming at 71.8% (n=272). Most households were semi-permanent at 79.9% with the rest being grass thatched and permanent at 10.1% (n=38) and 10% (n=38) respectively. In terms of size of households, most of them had 5-6 members at 39.3% (n=149) followed by 3-4 members at 29.3% (n=111). Very few households have 1-2 members at only 10.3% (n=39). There was fare distribution of respondents across the nine locations within the study area with the highest number drawn from sublocations within North sakwa ward at 50.4% (n=191). The discrepancy in the above totals was due to variations in responses by the respondents on different questions.

4.2 Fecal Contamination Status of Shallow Wells

A total of 54 grab water samples were collected from 54 sampled shallow wells out of a total of 180 shallow wells present in Dede Division. These sampled shallow wells served 386 households out of the 4008 house holds in total using shallow wells as source of water.

4.2.1 Hydrogen Sulphide (H2S) Rapid Field Test Results

As soon as grab water sample were collected, each of the 54 samples were tested for presense of total corliforms using H_2S kit as described in subsection 3.11.3. The results indicated that of the 54 water samples collected, 96.3% (n=52) of them tested positive for total corliforms. The positive samples were then safely transported in light proof insulated box with melting ice-packs to the laboratory for fecal corliform analysis.

4.2.2 Laboratory Test Results for Fecal Corliforms

Using the filter membrane technique, majority of the water samples from shallow wells in Dede Division tested positive for *Escherichi coli* 69% (n=36) showing presense of fecal matter (figure 4.1).

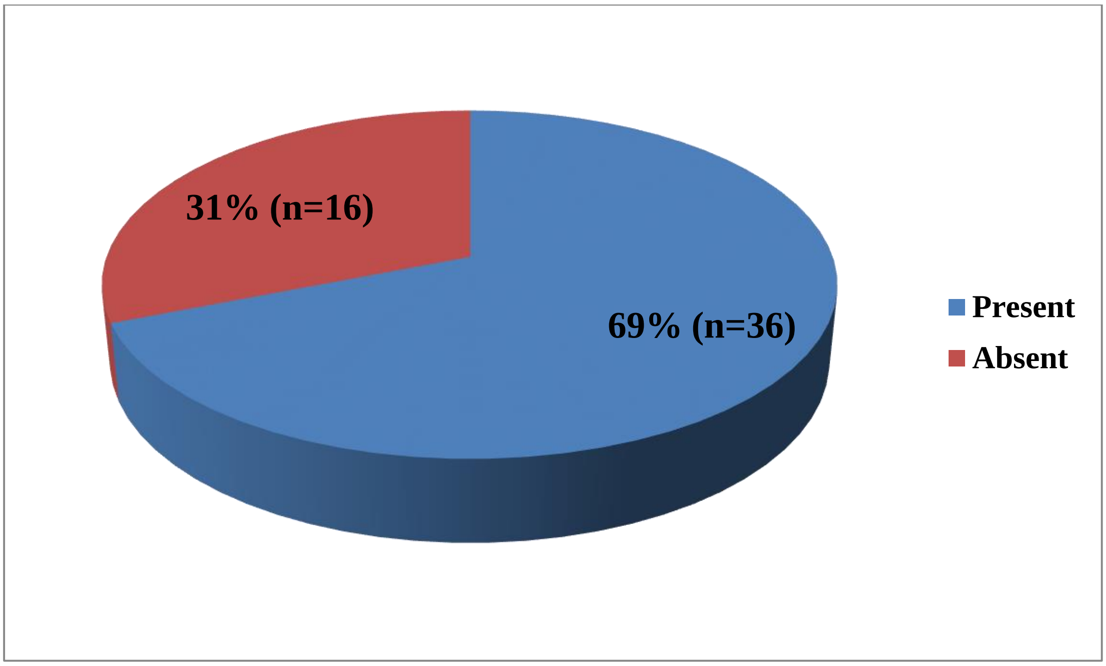

Figure 4.1: Fecal contamination Status of water samples from shallow wells in Dede Division during the month of March 2016.

4.3 Human Determinants of Fecal Contamination Status of Shallow Wells

4.3.1 Knowledge on Common Fecal Contamination Routes of Shallow Wells

4.3.1.1 Construction of Shallow Wells too close to a Latrine

Most of the respondents 56.58% (n=215) agreed that constructing a shallow well to close (<10m) to a latrine is a potential route for fecal contamination, while 43.68% (n=166) disagreed.

4.3.1.2 Construction of Shallow Wells Downhill a Latrine

As to whether constructing a well downhill a latrine is a route of fecal contamination of shallow wells, 59.26% (n=224) were in agreement while 40.78% (n=154) were not in agreement.

4.3.1.3 Open/Uncovered Well and Surface Runoffs

Majority of the respondents in Dede Division 58.31% (n=221) are aware that leaving a shallow well uncovered is a potential route of fecal contamination with 41.69%

(n=158) not aware. However, the study findings further revealed that a minority of the respondents 48.81% (n=185) agreed that surface runoff is a possible route of fecal contamination of shallow wells while 51.19% (n=194) descented.

4.3.1.4 Use of a Dirty Drawer

A substancial majority 50.66% (n=192) of Dede Division residents are aware that fetching water from a shallow well using a dirty drawer is a potential risk factor of fecal contamination of the well with an equally substancial minority 49.34% (n=187) not aware.

4.3.1.5 Human/Animal Feces dropping in a Shallow Well

A very significant majority 60.69% (n=230) disagreed with the fact that Humans and animal feces droping in a shallow well is a potential route of fecal contamination with only 39.31% (n=149) in agreement, serious pointer of low knowledge levels in this regard.

Table 4.3: Chi-square test Results between Knowledge on Fecal Contamination Routes and Fecal Contamination Status of Shallow Wells

		Fecal Contamination Status		
Common knowledge on Fecal Cont. Routes	**Scale**	**Present**	**Absent**	**Chi Square Test**
Well too close (<10M) to latrine	SA	25.9%	7.4%	
	A	17.9%	5.5%	
	D	13.2%	7.4%	
	SD	12.1%	10.6%	x^2= 17.41; df=3; P=0.001*
Well downhill a Latrine (in terms of Gradient)	SA	19.8%	7.4%	
	A	23.5%	8.5%	
	D	19.1%	8.5%	
	SD	6.6%	6.6%	x^2 =10.32; df=3; P=0.016*
Open/uncovered well (unprotected)	SA	18.5%	22%	
	A	26.6%	7.4%	
	D	15.3%	8.2%	
	SD	8.7%	9.5%	x^2 =22.49; df=3; P<0.001*
Surface Runoffs	SA	13.2%	2.6%	
	A	23.2%	9.8%	
	D	21.6%	13.2%	
	SD	11.1%	5.3%	x^2 =8.86; df=3; P=0.031*
Using Dirty Drawer	SA	13.2%	4%	
	A	25.6%	7.9%	
	D	17.4%	9.5%	
	SD	12.9%	9.5%	x^2 =12.13; df=3; P=0.011*
Human/Animal feces Droping in the well	SA	11.1%	1.8%	
	A	18.5%	7.9%	
	D	29%	12.4%	
	SD	10.6%	8.7%	x^2 =13.44; df=3; P=0.004*

Significant at p<0.05

As outlined in table 4.3 above, there was a significant relationship between level of knowledge of respondents on a well being too close to a latrine as a potential route (risk factor) of fecal contamination and actual fecal contamination status of shallow wells (x^2=17.41, p=0.001, df=3). The study further observed very significant relationships between levels of knowledge of respondents on a well located downhill a latrine (x^2 =10.32, df=3, p=0.016), an open/uncovered well (x^2=22.49**,** df=3, p<0.01), surface run-offs into wells (x^2 =8.86, df=3, p=0.031), using a dirty drawer (x^2 =12.13, df=3, p=0.011), people/animals dropping in wells (x^2 =14.65, df=3, p=0.004), and human/animal feces dropping in the well (x^2 =13.44, df=3, p=0.004) as potential routes (risk factors) of fecal contamination and actual contamination status of shallow wells.

Table 4.4: Chi-square test Results on further Relationships between knowledge on Fecal Contamination Routes and Fecal Contamination Status of Shallow Wells

		Fecal Contamination Status		
Common knowledge on Fecal Cont. Route	**Scale**	**Present**	**Absent**	**Chi-Square Test**
Well close to rubbish pit	SA	14.2%	4.5%	
	A	23.2%	7.4%	
	D	19.5%	7.9%	
	SD	11.9%	11.3%	x^2 =8.98; df=4; P=0.062
High Rainfal Frequency	SA	7.9%	2.9%	
	A	28%	10.6%	
	D	20.9%	5.8%	
	SD	12.4	11.4%	x^2 =2.11; df=3; P=0.551
Earth dropping from unprotected well wall	SA	11.9%	5%	
	A	23%	6.9%	
	D	21.4%	10.3%	
	SD	12.9%	8.7%	x^2 =6.84; df=3; P=0.077

As outlined in table 4.4, there were no significant relationships between level of knowledge on a shallow well being too close to a rubbish pit (x^2=8.98, df=3, p=0.062), high rainfall frequency (x^2=2.11, df=3, p=0.551), earth dropping from unprotected walls of the well (x^2=6.84, df=3, p=0.077) and fecal contamination status of shallow wells respectively.

4.3.2 Human Hygiene Practices

4.3.2.1 Washing Hands After Handling Farmyard Manure at the Shallow Well

The study findings revealed that a significant 76% (n=288) of respondents in Dede Division wash their hands at the shallow wells after handling farmyard manure with only 24% (n=91) not washing at the shallow well, a practice that increases susceptibility of the well to fecal contamination.

4.3.2.2 Cleaning Baby Nappies next to the shallow Well

Majority of the study respondents 60.9% (n=231) wash baby nappies next to the shallow wells while 39.1% (148) do not. This is very significant given the potential risk this practice creates in as far as fecal contamination of shallow wells is concerned.

4.3.2.3 Treating and Disinfecting Wells

Most respondents 93.1% (n=353) reported treating their shallow wells with only 6.9% (n=26) not treating/disinfecting their shallow wells.

4.3.2.4 Shallow Well Treatment Method

The findings revealed that the most common method of shallow well treatment is pouring Liquid chlorine at 40.4 % (n=153). Other methods include removal of mud at 28.8% (n=109), and lastly dewatering the well at 15% (n=57) respectively.

Table 4.5: Results on the relationships between Human Hygiene Practices and Fecal Contamination Status of Shallow Wells

Human Hygiene Practice	**Fecal Contamination Status**			
Risk Factor	**Scale**	**Present**	**Absent**	**Chi Square Test**
Washing hands after handling manure at well	Yes	57.3%	29.3%	
	No	11.9%	1.6%	x^2 =15.44; df=1; P<0.001*
Washing hands after visitig Toilets/latrines	Yes	57.3%	29.3%	
	No	11.9%	1.6%	x^2 =15.44, df=1, p<0.001*
Cleaning baby nappies next to the well	Yes	48.5%	27.4%	
	No	20.6%	3.4%	x^2 =0.38; df=1; P=0.54
Treating & disinfecting well	Yes	41.4%	19.5%	
	No	27.7%	11.3%	x^2 =1.71; df=1; P=1.911
Well treatment Method	Yes	65.2%	28%	
	No	4%	2.9%	x^2 =8.87; df=1; P=0.067

***Significant at p<0.05**

The study findings as shown in Table 4.5 above revealed a significant association between washing hands after visiting latrines as a human hygiene practice (x^2 =10.08, df=1, p=0.001) and fecal contamination status of shallow wells with a significant majority of respondents 86.5% (n=328) reporting washing their hands after visiting toilets. However, 48.5% (n=96) of those who wash their hands either do so on top of the well or a distance less than 5M from the draw point. The results futher revealed a very significant association between handwashing after handling manure (x^2 =15.44, df=1, p<0.001) and fecal contamination status of shallow wells. However, 76%

(n=288) of them wash their hands at the well, with 56.6% (n=204) either washing on top of the well or a distance less than 5M from the draw point.There were no significant associations between cleaning of baby nappies (x^2=df=1p=0.540), treatment/disinfection of wells (x^2 =1.71, df=1, p=0.191), well treatment method (x^2 =8.87, df=1, p=0.067,) and fecal contamination status of shallow wells respectively. Figure 4.2 below shows that 93.1% (n=353) of respondents treat/disinfect their wells.

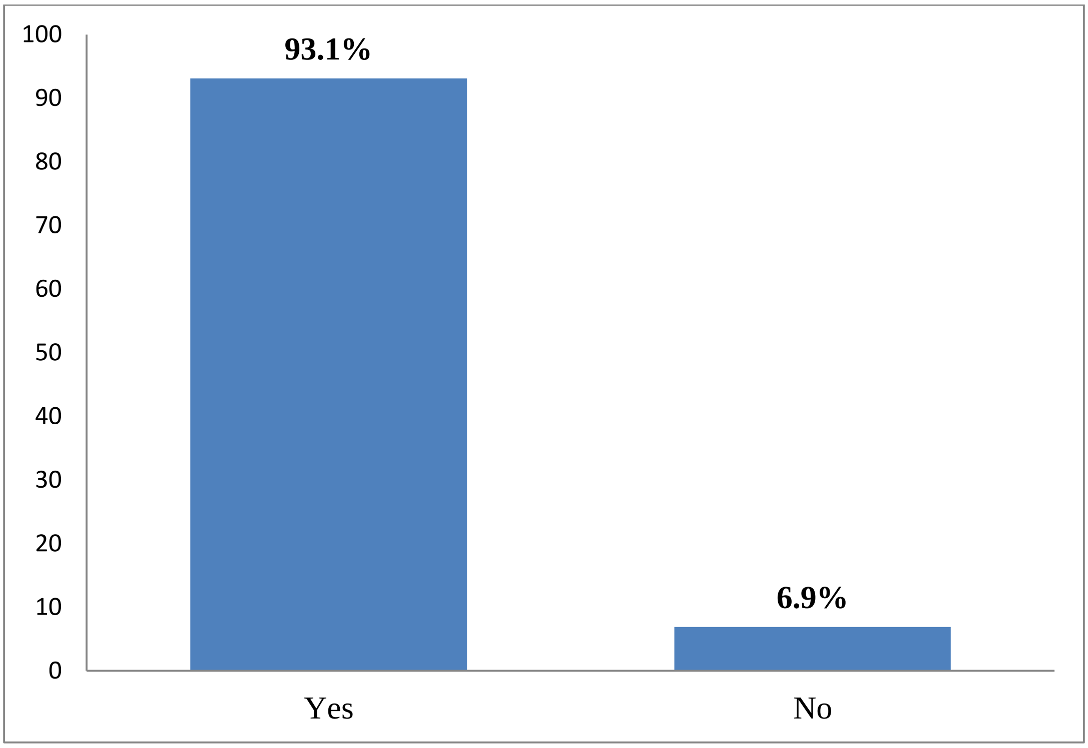

Figure 4.2: Distribution of Respondents Treating their Shallow Wells

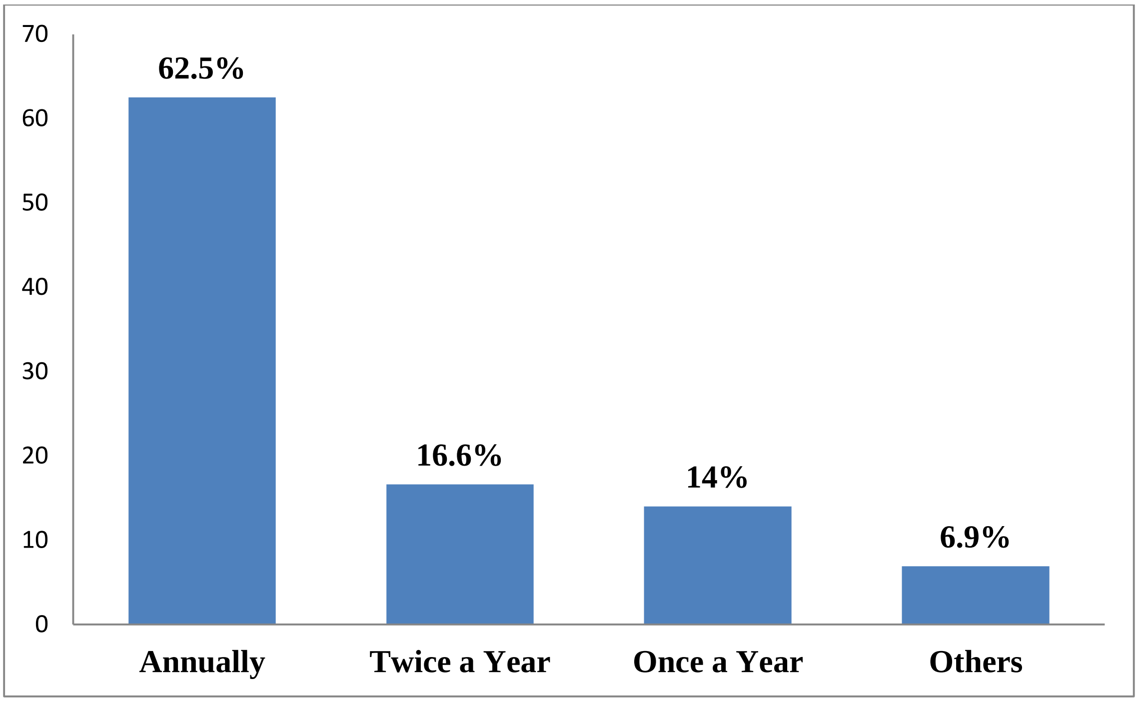

Figure 4.3: Frequeny of Treatment of Shallow Wells

The findings further indicated that 53.8% (n=166) of respondents remove mud and dewater their wells as a means of treatment, with about 40.4%(n=158) pouring liquid chlorine.

4.3.3 Human Sanitary Practices

4.3.3.1 Location of Pit Latrines in relation to a Shallow Well

The study findings revealed that majority of the pit latrines 79.7% (n=302) are constructed more tham 10M away from the shallow wells with 20.3% (n=77) constructed within 10M from the shallow well. However, 66.5% (n=253) of pit latrines nearest to the shallow wells are erected on lower ground (interms of gradient) with only 33.5% (n=127) erected on higher ground in Dede Division.

4.3.3.2 Drainage Channels and Floors of Shallow Wells

Minority of the shallow wells 39.3% (n=21) had faulty drainage channels potencially capable of permiting ponding around the shallow wells with a significant majority 60.9% (n=33) having proper drainage channels. In addition, 85% (n=46) of shallow wells in Dede Division had their concrete floors more than 1M wide, a significant pointer to proper sanitary maintenance while 15% (n=8) only had their floors less than 1M wide.

4.3.3.3 Walls of Shallow Wells

Study findings further revealed that majority walls of shallow wells 85.2% (n=323) were adequately sealed at any point 3M below the ground with only 14.8% (n=56) not adequately sealed. In addition, 65.2% (n=147) had visible cracks on on the cover wall around the respective shallow wells, with only 34.8% (n=132) without cracks.

4.3.3.4 Drawers and Covers

A significant majority of shallow wells 60.7% (n= 230) had their drawers (ropes and buckets) left in positions of possible contaminations e.g. next to animal droppings with the rest 39.3% (n=149) well placed. Over 82.1% (n=311) of shallow wells required a cover with only 17.9% (n=68) of them covered.

4.3.3.5 Human and Animal Feces

The findings revealed that 96.3% (n= 365) had human feces absent within 10M of the shallow wells while 3.7% (n=14) had human feces present. However, 69.9% (n=264) had animal droppings present within 10M while 30.4% (n=115) did not have them.

Table 4.6: Association between Human Sanitary Practices and Fecal contamination Status of Shallow Wells

Human Sanitary Practices		**Fecal Contamination Status**		
Risk Factor	**Categories**	**Present**	**Absent**	**Chi-square**
Latrine within 10M of the Well	Yes No	53.8% 15.3%	5% 25.9%	x^2 =4.27; df=1; p=0.187
Latrine on higher ground than the well	Yes No	29.3% 39.8%	4.2% 26.6%	x^2 =24.38; df=1; P<0.001*
Faulty drainage channel permiting ponding	Yes No	22.4% 46.7%	10% 20.8%	x^2 =3.32; df=1; P=0.68
Concrete floor <1M wide around the well	Yes No	8.2% 60.9%	6.9% 24%	x^2 =6.83; df=1; P=0.009*
Walls of well inadequately sealed at any point 3M below the ground	Yes No	13.2% 55.9%	1.6% 29%	x^2 =9.34; df=1; P=0.002*
Cracks in the concrete wall around the well	Yes No	30.1% 41.7%	7.4% 23.5%	x^2 =6.83; df=1; P=0.003*
Ropes and buckets left in position of possible contamination	Yes No	42.5% 26.6%	18.2% 12.7%	x^2 =0.21; df=1; P=0.648
Well require a cover	Yes No	58.3% 10.8%	23.7% 7.1%	x^2 =3.03; df=1; P=0.820
Installation require fencing	Yes No	48.8% 20.3%	21.1% 9.8%	x^2 = 0.19; df=1; P=0.661
Human feces present within 10M of the well	Yes No	1.3% 67.8%	2.4% 28.5%	x^2 =7.61; df=1; P=0.006*
Animal droppings present within 10M of the well	Yes No	24.3% 44.7%	5.8% 25.1%	x^2 =10.84; df=2; P=0.004*

Significant at p<0.05

The study found out that there were significant associations between latrines located on higher ground in relation to shallow well (x^2 =24.38, df=1, p<0.001), shallow wells with concrete floors less than 1M around the well (x^2=15.94, df=1, p=0.009), walls inadequately sealed 3M below the ground (x^2 =9.34, df=1, p=0.002), cracks in concrete walls around the shallow wells (x^2 =6.83, df=1, p=0.003), human feces present within 10M from the shallow well (x^2 =7.61, df=1, p=0.006), animal droppings present within 10M from the shallow well (x^2=10.84, df=2, p=0.004) and fecal contamination status of corresponding shallow wells respectively. In all the categories listed above, majority of shallow wells tested positive for fecal corlirforms as shown in table 4.22. However, other categories of sanitary practices had no significant association with fecal corliform status of shallow wells. These included latrines located within 10M of the well (x^2=4.27, df=1, p=0.187), presence of other sources of pollution like animal excreta and rubbish (x^2 =0.19, df=1, p=0.784), faulty draining channels permiting ponding at (x^2=3.32, df=1, p=0.068), ropes and buckets left in positions of possible contamination (x^2 =4.21, df=1, p=0.648) respectively.

Table 4.7: Technical Determinants Results

Technical Determinants	**Categories**	**n**	**%**
Distance in Meters from the nearest latrine to the well	6-10	15	28%
	11-15	15	28%
	>15	24	44%
Distance in Meters from the nearest cattle pen (if any) to the well	1-5	2	4%
	6-10	22	40.6%
	11-15	2	4.2%
	>15	28	51.2%
Well location in relation to the nearest cattle pen (if any)	Down hill	19	35.6%
	Uphill	32	59.9%
	Relatively flat Ground	2	4.5%
Damage to or lack of concrete plinth	Yes	16	29.8%
	No	37	70.1%
Breaks/cracks on the parapet wall	Yes	25	45.4%
	No	29	54.6%
Breaks/cracks in the cover/top slab	Yes	28	51.2%
	No	26	48.8%
Breaks in the Drainage channel	Yes	24	44.1%
	No	30	65.9%
Well covered while not in use	Yes	12	21.9%
	No	42	78.1%
Well Area fenced out	Yes	21	38.6%
	No	33	61.2%

4.4 Technical Determinants of Fecal Contamination Status of Shallow Wells

As shown in table 4.7 above, 44% (n=24) of pit latrines in Dede Division are located more than 15M away from shallow wells, with 28% (n=15) of the pitlatrines located 6-10M and 11-15M away respectively. Majority 51.2% (n=28) of cattle pens within homesteads are located more than 15M away from the respective shallow wells, 40.6% (n=22) located 6-10M away, 4.2% (n=2) located between 11-15M away and the rest 4% (n=2) located between 1-5M away from the nearest shallow well. Most shallow wells 59.9% (n=32) are located uphill in relation to the nearest cattle pen (if any), with 35.6% (n=19) located down hill and only 4.5% (n=2) located on a relatively flat ground in relation to the nearest cattle pens. A significant majority 70.1% (n=37) of shallow wells had no damage to or lack of a concrete plinth with only 29.8% (n=16) having damaged/cracked plinths. Most shallow wells 54.6% (n=29) had no significant cracks/breaks on their parapet walls with about 45.4% (n=25) having the same. The study further observed that a significant majority 51.2% (n=28) of shallow wells in Dede Division had breaks/cracks in the cover/top slab with about 48.8% (n=26) with no cracks on the top slab. A minority 44.1% (n=24) had breaks in their drainage channels with the majority 65.9% (n=30) having no breakson their drainage channels. Very few wells 21.9% (n=12) are covered while not in use while over 71.8% (n=42) are not covered while in use. Finally, it was observerd that a significant majority 61.2% (n=33) of shallow well areas in Dede Division are not fenced with only 38.6% (n=21) of them fenced out.

Table 4.8: Association between Technical Determinants and Fecal Contamination Status of Shallow Wells

Technical Determinants		Fecal Contamination Status		
Risk Factor	**Categories**	**Present**	**Absent**	**Chi-square**
Distance (M) from nearest latrine to the well	6-10	11.9%	16.1%	
	11-15	23.7%	4.2%	
	>15	33.5%	10.6%	x^2 =51.46; df=2; P<0.001*
Distance (M) from nearest cattle pen (if any) to the well	1-5	2.9%	1.4%	
	6-10	25.2%	18.9%	
	11-15	2.9%	1.7%	
	>15	37.8%	9.2%	x^2 =20.90; df=4; P<0.001*
Location of the well in relation to the nearest cattle pen (if any)	Downhill	46.6%	16.1%	
	Uphill	11.3%	12.5%	
	Relatively flat ground	11.3%	22.5%	x^2 =22.97; df=3; P<0.001*
Damage to or lack of concrete plinth	Yes	25.4%	7.2%	
	No	42.9%	24.5%	x^2 =8.53; df=2; P=0.014*
Breaks/cracks on the parapet wall	Yes	24.9%	6.3%	
	No	47.2%	21.6%	x^2 =9.81; df=2; P=0.007*
Breaks/cracks in the cover/top slab	Yes	26.2%	12.3%	
	No	45.8%	15.6%	x^2 =7.42; df=2; P=0.024*
Breaks in the Drainage channel	Yes	6.3%	10.6%	
	No	65.8%	17.3%	x^2 =40.94; df=2; P<0.001*
Well covered while not in use	Yes	1%	0.7%	
	No	71.1%	27.2%	x^2 =6.37; df=2; P=0.041*
Well Area fenced out	Yes	19.9%	3%	
	No	52.2%	25%	x^2 =15.29; df=2; P<0.001*

***Significant at 0.05**

As outlined in table 4.8 above, study findings revealed very significant associations between several technical determinants and fecal contamination status of shallow wells. Distance in meters from a latrine to a well had a significant association with fecal corliform presence in wells (x^2 =51.46, df=2, p<0.001), with majority of wells within safe distances of contamination (>10M) but still tested positive for fecal corliforms. In addition, Distance in meters from the nearest cattle pen if any had a significant association with fecal contamination status of the wells (x^2 =22.97, df=2, p<0.001) with a significant majority of shallow wells testing positive for fecal corliforms.The study further revealed significant associations between damage or lack of concrete plinth (x^2 =8.53**,** df=2, p=0.014), breaks/cracks on the parapet walls if any (x^2 =9.81**,** df=2, p=0.007), breaks/cracks in the cover/top slab if any (x^2 =7.24, df=2, p=0.024), breaks in the drainage channels (x^2 =40.29 df=2, p<0.001), shallow well covered while not in use (x^2 =6.37**,** df=2, p=0.041), shallow well fenced out (x^2 =15.29, p<0.001, df=2) and fecal contamination status of the wells respectively.

Table 4.9: Further Association between Technical Determinants and Fecal Contamination Status of Shallow Wells

Technical Determinants		**Fecal Contamination Status**		
Risk Factor	**Categories**	**Present**	**Absent**	**Chi-square**
Location of the well in relation to the nearest Latrine	Downhill	27.2%	8.4%	
	Uphill	38.8%	21.1%	
	Relatively flat ground	3.2%	1.3%	x^2 =5.29; df=1; P=0.071
Well protection status	Protected	21.6%	11.6%	
	Unprotected	47.5%	19.3%	x^2 =1.45; df=1; P=0.228

As shown in table in table 4.9 above, the chi square analyisis run further revealed no association between location of the well in relation to the nearest latrine (x^2 =5.29, df=2, p=0.071), well protection status (x^2 =1.45, df=1, p=0.228,) and fecal contamination status of shallow wells respectively.

4.5 Hypothesis one Test Results

Table 4.10: Multinomial Logistic Regression Analysis of Human Determinants as a Function of Fecal Contamination Status of Shallow Wells

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	**Sig.**
Intercept Only	465.400			
Final	273.513	191.887	65	<0.001*

Significant at 0.05*

As outlined in table 4.10 above, the study established that human determinants in general are a function of fecal contamination status of shallow wells at (p<0.001) there by rejecting the null hypothesis, "Human determinants are not a function of fecal contamination status of shallow wells," and subsequently failing to reject the alternative. This therefore means that human determinats are predictors (pointers) of fecal contamination status of shallow wells in Dede Division, Migori County, Kenya.

Table 4.11: Multinomial Logistic Regression Analyisis of Technical Determinants as a function of Fecal Contamination Status of shallow Wells

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	**Sig.**
Intercept Only	389.198			
Final	147.382	241.816	20	<0.001*

***Significant at 0.05**

As outlined in table 4.11 above, the analysis affirmed that technical determinants in general are a function of fecal contamination status of shallow wells at ($p<0.001$) there by rejecting the null hypothesis, “Technical determinants are not a function of fecal contamination status of shallow wells,” and failing to reject the alternative. This therefore means that technical determinats generally are predictors (pointers) of fecal contamination status of shallow wells in Dede Division, Migori county, Kenya.

CHAPTER FIVE: DISCUSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter presents a discussion of the results of the study "Determination of Fecal Contamination Status of Shallow Wells in Dede Division, Migori County, Kenya," together with conclusions and recommendations based on the study findings.

5.2 Fecal Contamination Status of Shallow Wells

As shown in figure 4.1 above, a significant majority of shallow wells (69%) tested positive for *Escherichi Coli*, a strong indicator for presence of fecal corliforms in water, with only 31% testing negative showing absence of fecal matter. This concurs with a study conducted in Conakry, Guinea, which showed widespread contamination of shallow dug wells (Howard *et al.* 2003). This is true given the multiple human and technical risk factors significantly associated to fecal contamination status of shallow wells.

5.3 Human Determinants of Fecal Contamination Status of Shallow Wells

5.3.1 Knowledge on Fecal Contamination Routes

Various knowledge levels of respondents on possible fecal contamination routes of shallow wells were evaluated for their likelihood of causing contamination. A shallow well dug too close to a latrine, a well downhill a latrine, an open/uncovered well, presence of a faulty septic tank, surface runoffs, dropping objects in wells, using dirty drawers, laundrying next to the well and human and animal feces dropping inside the well were found to be highly significant predictors of fecal contamination of shallow wells (see table 4.3). These concur with a study by Dighton which revealed that fecal contamination can reach ground water sources, including drinking water wells, from failed septic systems, leaking sewer lines, by passing through the soil and large cracks in the ground. Domestic pets, especially dogs, and cats can contribute to fecal contamination of well waters. Runoff from roads, parking lots, and yards can carry animal wastes to unprotected wells through erosion (Dighton, 2010). A study by Donderski and Wilk (2008), further concurs with these findings revealing that the major culprit of well water faecal contamination emanates from poor positioning of pit latrines particularly in rural areas and slums. They further report that most infrastructural investors do not adhere to the regulations by authorities on the distance hence they end up constructing latrines at close (less than 30 meters apart) proximity to the wells. However, having a well too close to rubbish pit, and high rainfal frequency respectively, were not significant predictors of routes of fecal contamination of shallow wells (see table 4.3). This may be attributed to the fact that rubbish pits are not primarily filled with human/animal waste and fecally contaminated wastes which are potential sources of contamination.

5.3.2 Human Hygiene Practices

As shown in table 4.5 above, Washing hands after visiting toilets and after handling manure at the well were highly significant predictors of fecal contamination status of shallow wells respectively. In as much as it's a good practice, a significant majority (48.5%), of those who wash their hands after visiting toilets do so on top of the well. This may either contaminate the drawers or wash off traces of fecal matter back into the well hence contamination. However, cleaning baby nappies next to a shallow well was not necessarily a predictor of fecal contamination (p=0.54). It was noted however, that 60.9% of the respondents still clean baby nappies next to the well, as a result exposing the shallow wells to fecal contamination. This may be as a result of lack of access to modern disposable dipers in rural settings or very low income levels by households. This concurs with a study by Conboy and Goss (2009), which affirms that people who handle fecal wastes particularly from children and the disabled around water sources for convenience end up contaminating the water with feces, as a result exposing themselves to fecal related diseases. In spite of 93.1% of respondents reporting treating their wells, well treatment was not a significant predictor of fecal contamination (p=0.191). This may be attributed to inefficient methods of treatmet.

5.3.3 Human Sanitary Practices

During the study, a sanitary inspection of immediate surrounding environments of different sampled shallow wells was conducted to identify possible fecal contamination sources and pathways of shallow wells. Much as there are many influences on microbiological contamination of shallow wells reflecting several different mechanisms by which microbes derived from faeces may enter the water in the well, study findings show that latrines constructed on higher groung than wells were significantly associated with fecal contamination status of corresponding shallow wells (p=0.000). This enhances movement of fecal corliforms within the soil through leaching and filtration to the near shallow well water sources. The findings further revealed that concrete floors <1M wide around the well (p=0.000), walls of wells inadequately sealed at any point 3M below the ground (p=0.000), cracks in the concrete wall around the well (p=0.003), human feces present within 10M of the well (p=0.006), and animal droppings present within 10M of the well (p=0.004), were human sanitary practices significantly associated with fecal contamination status of shallow wells. These concure with a study conducted in Conakry, Guinea, which showed that there was widespread contamination of shallow dug wells and suggested that microbiological contamination was associated with poor maintenance (human sanitary practices) of the wells rather than sub-surface leaching of faecal material (Howard *et. al*, 2003). However, sanitary risk factors such as a well requiring a cover (p=0.820), ropes and buckets left in positions of possible contamination (p=0.648), well installation requiring fencing (p=0.661), were not significantly associated with fecal contamination of shallow wells. This is contrary to a study by (Rojas *et. al*, 2004) which found that factors such as the presence of uncapped wells and poor sanitary completion were as important as sub-surface leaching of microbiological contaminants. The total sanitary risks scores showed a significant association with fecal contamination status of shallow wells.

5.4 Technical Determinants of Fecal Contamination of Shallow Wells

The results outlined in table 4.8 above indicate that distance in Meters from the nearest latrine, the nearest cattle pen and location of the well in relation to the nearest cattle pen were highly significant technical determinants of fecal contamination status of shallow wells (p=0.000). About 56% of shallow wells are located less than 15 meters from the nearest latrine while 44.1% are located more than 15 meters. This disagrees with a study by AMREF standards which affirms that a pit latrine should be sited/located a minimum distance of 30 meters from a well or a water source and more than 10M away from a residential area (AMREF, 2001). However, according to WHO, the minimum safe distance should be determined from the time taken by contaminants to travel from their source to the source of drinking-water. This will depend on local conditions, the most important of which are the geological and hydrogeological conditions of the area, the quantity of faecal matter likely to be discharged, and the number of existing and planned sources of contamination (WHO, 1997).

The study further revealed that technical aspects like damage to or lack of a concrete plinth, breaks or cracks on the parapet wall,breaks or cracks in the cover/top slab, breaks in the drainage, a well covered while not in use, well area fenced out and type of shallow well respectively, were significant technical determinants of fecal contaminations status of shallow wells (see table 4.8). This concurs with a study by Obura and Mwanthi which revealed that the sides of a water well should be lined with impervious material to the depth of about 3 meters, and incase of deep wells upto the 1st impervious stratium. The top should be covered by a concrete apron which drains away from the entrance of the well (Obura & Mwanthi, 2014). They futher show that a drain should be provided around the apron to drain spilled water away from the well. The method of water extraction should be improved and where possible a pump used (Obura & Mwanthi, 2014). Another study by WHO further affirms that open or poorly covered well heads pose the commonest risk to well-water quality, since the water may then be contaminated by the use of inappropriate water-lifting devices by consumers (WHO, 1997). However, location of the well in relation to the nearest latrine was not insignificant (p=0.071). This could be attributed to the fact that other factors such as hydrogeology of the soil influenced the outcome. Well protection status too, was not a significant predictor of contamination (p=0.228), though 68.8% were unprotected, meaning factors other than protection influenced fecal contamination status of shallow wells.

5.5 Conclusion

Firstly, A significant majority of shallow wells in Dede Division are fecally contaminated.

Secondly, human determinants are a function of fecal contamination status of shallow wells in Dede division, that is, a shallow well constructed too close to a latrine, a shallow well down-hill a latrine, open or uncovered shallow well, surface runoffs, using a dirty drawer, doing laundry next to a well, human and animal faeces dropping in the well, washing hands after visiting latrines/toilets at the well and washing hands after handling manure at the well, were found to be significant determinants of fecal contamination of shallow wells. In addition, latrines on higher ground than the well, cracks in the concrete wall around the well, human feces presence within 10M of the wells and animal droppings presence within 10 meters are highly significant pointers of fecal contamination of shallow wells.

Lastly, Technical determinants are a function of fecal contamination status of shallow wells in Dede Division, that is, distance in meters from the nearest latrine to the well, from the nearest cattle pen, damage to or lack of concrete plinth, breaks or cracks on the parapet wall, well covered while not in use and type of shallow well were higly significant technical determinants of fecal contamination status of shallow wells. This clearly affirms that efficient protection of shallow wells is a critical pointer to their ground water quality. However, well protection status was not associated to fecal contamination status of the respective shallow wells. This demonstrates that poor maintenance of already protected wells can contribute to pollution of shallow wells with fecal matter.

5.6 Recommendations

i. Households in Dede Division should ensure adequate treatment of shallow wells for fecal contamination before utilization of water from these sources. This can be both at source or household level.
ii. Households in Dede Division should be sensitized by the relevant authorities on common routes of fecal contamination of shallow well water and safe hygiene and sanitation practices around shallow wells to prevent fecal contamination of the wells.
iii. Households using shallow wells in Dede Division should ensure proper sighting and location of latrines in relation to shallow wells to avoid fecal

contamination of the wells through leaching. The pit latrines should be sighted down hill the shallow wells and located atleast 10 meters apart.

5.7 Further Research

i. A study should be carried out on the prevalence of *Klebsilla*, a pathogenic micro-organism that naturally exists in contaminated water and its impacts on public health since it was noted in most of the samples.

ii. A study on the level of contamination of shallow wells by individual fecal corliforms should be conducted as this would help point them to the rising trends of fecal related disease burden in Dede Division and another on whether soil type and hydrogeology influence fecal contamination status of shallow wells.

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APPENDICES

APPENDIX I: INFORMATION AND CONSENT FORM

My name is OluochEvanceOdiwuor, a student at Kenyatta University pursuing Master of Science in Environmental Health. I am carrying out a study on “Determination of Fecal Contamination Status of Shallow Wells in Dede Division, Migorycounty, Kenya.”The information is for my academic purposes and may help the ministry of Health and environment with baseline data that can help them on intervention strategies on health risks of noise.

Study Procedures

In this study, my research assistants and I will provide a self-administered questionnaire outlining demographic characteristics and possible human determinants of fecalcontamination status of shallow wells for you to answer. In Addition, a checklist will be used to assess technical determinants i.e, observable sanitary risks around sampled shallow wells, well protection status and siting/location of the wells.

You reserve the right to decline participation in this study. You will continue with your normal operations at home as usual whether you agree to participate in the study or not and your decision will not affect your way of life in any way.Participation in this study is voluntary and you may ask questions related to the study at any time.

You may refuse to respond to any questions and you may stop an interview at any time. You may also stop being in the study at any time without any consequences.

Discomforts and Risks

There will be no risks involved during research process since the questionnaires will self-administered and only those who request to be assisted will be helped out by the research assistants. There will be no chemicals or drugs that will be ingested or administered neither sample that will be collected during the study that may amount to any adverse effects. The interview will take less than one our of your time.

Benefits

The findings may be vital in coming up with the most efficient and adequate intervention measures of reducing fecal contaminations of shallow well waters hence significantly reduce or eliminate continued incidences of morbidity and mortalities resulting from fecal-related diseases. The findings may also help come up with effective recommendations for well water protection and siting about latrines and waste disposal sites. This may significantly reduce or eliminate reoccurrence of fecal-related diseases and by extension reduction in communicable disease burden within the Sub-County.

Reward

If you agree to participate in this study, there will be no reward given.

Care and Protection of Research Participants

The participants in this study will be household heads whose members use water from shallow wells. The questionnaires will be issued privately at their homes or at any other place as will be preferred by them. Data collection Procedures will be followed carefully to ensure the participants are as comfortable as possible with the process.

Confidentiality

The questionnaires will be issued privately at home or any other place convenient for the participant. Your name will not be recorded on the questionnaire .All the information you will provide will be confidential and only shared by supervisors. The questionnaires will be kept in a locked cabinet for safe keeping and everything will be kept private.Your responses in this study are very important and you are highly encouraged to participate.

Contact Information

If you have any questions, you may contact the following:

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chairman.kuerc@ku.ac.ke or secretary.kuerc@ku.ac.ke

Participant's Statement

I confirm that I have been informed about the purpose, duration, benefits and the risks of this study and my participation in the process. I acknowledge that I am free to withdraw from the study at any stage if so I wish, without giving any explanation and that I will not be compromised in any way since my participation is voluntary. I have been assured of confidentiality in all the information that I will provide. I have been given chance to ask questions and they have been answered to my satisfaction. I am also aware that the information I provide may be published, but my name will not appear on any part of the study, nor will any information that may identify me be used in the study. I therefore, accept willingly to participate in the study.

:........……………………......

....

Signature or Thumb Print Date

Investigator Statement

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

Name of the Researcher.

....

....

Signature/Thumbprint Date

APPENDIX II: QUESTIONNAIRE

QUESTIONNAIRE CODE………….. CORRESPONDING WELL CODE………..

Instructions: *Put a tick (√) in the box adjacent to the most appropriate response.*

SECTION A: DEMOGRAPHIC DATA

1. What is your age bracket?

18-22 { } 23-27{ } 28-32{ } 33-37{ } 38-42{ } 43 and above { }

2. Your sex?

Male { } Female { }

3. Your occupation?

Self-employed { } Employed { } unemployed { }Other (specify)………………

4. What is your level of education?

None { } Primary { } Secondary { } College { } University { }

5. What is your religion?
   Christian { } Islam { } Other(specify)……………………………..
6. What is your main Economic Activity?
   Faming{ } Livestock Rearing { } Both{ } Other (specify)……………….
7. Type of Housing
   Grass thatched { } Semi-permanent { } permanent { }
8. Household size (no. of members); 1-2{ } 3-4{ } 5-6{ } 7-8{ } 9-10{ } >10{ }

SECTION B. HUMAN DETERMINANTS

A) KNOWLEDGE ON POSSIBLE FEACAL CONTAMINATION ROUTES (WAYS)

9. Respond appropriately to the following: means in which well water can be polluted by human waste?

	SA	**A**	**D**	**SD**
a) A well too close to a latrine	{ }	{ }	{ }	{ }
b) A well downhill a latrine	{ }	{ }	{ }	{ }
c) An open/uncovered well	{ }	{ }	{ }	{ }
d) A well too close to a rubbish pit	{ }	{ }	{ }	{ }
e) Presence of faulty septic tanks	{ }	{ }	{ }	{ }
f) Surface Runoffs	{ }	{ }	{ }	{ }
g) High rainfall frequency	{ }	{ }	{ }	{ }
h) People dropping objects in the well	{ }	{ }	{ }	{ }
i) Dirty Equipment used to draw water	{ }	{ }	{ }	{ }
j) Dropping Earth from the unprotected Walls of the well	{ }	{ }	{ }	{ }
k) People and animals dropping in	{ }	{ }	{ }	{ }
l) Doing Landry Next to a Well	{ }	{ }	{ }	{ }
m) Presence of animal & human droppingswthin 10M from the well	{ }	{ }	{ }	{ }

B) HUMAN HYGIENE AND SANITATION PRACTICES

10. Do you wash hands after visiting toilets at the well?

Yes { }   No { }

If Yes above, where exactly?

On top of the well { } <5M from drawpoint{ }

5-9M from drawpoint{ }   10M> from drawpoint{ }

11. Do you wash your hands after handling farm yard manure at the well?

Yes { }   No { }

If Yes above, where exactly?

On top of the well { } <5M from drawpoint{ }

5-9M from drawpoint{ }   10M> from drawpoint{ }

12. Do you clean baby nappies next to the well?

Yes { } No { }

If Yes above, where exactly?

On top of the well { } <5M from drawpoint{ }

5-9M from drawpoint{ } 10M> from drawpoint{ }

12.Do you treat your well?

Yes { } No { }

If Yes above, how frequent do you treat and disinfect your well?

Annually { } Twice a year { } Once in two years { }

13. How do you treat your well?

Pouring liquid Chlorine { } Removal of mud { }

Dewatering the well { } Dipping solid chlorine{ }

THANK YOU!

APPENDIX III: CHECKLIST

Instructions:*Kindly observe and take note of the following on Sampled shallow (Hand Dug) Wells, within or outside Homesteads. Fill in or Put a tick* **(√)** *in the box adjacent to the most appropriate response.*

Part I: General Information

Well Code No:…………..………………..Date of visit:…………...............................
Name of Sub Location:……………………………Name of Villa……………………..
Type of ShallowWell**:**Open Hand Dug Well{ }
CoveredHand Dug Well with a Windlass{ }
Covered Hand Dug Well with Hand Pump{ }
Shallow Well Ownership: Private { }   Communal { }

Part II:Sanitary RiskAssesment of ShallowWells*(adapted from WHO,1997)*

#	**Specific Diagnostic Information forSanitary Assesment**	**YES**	**NO**
1.	Is there a latrine within 10 Meters (M) of the well?		
2.	Is the nearest latrine on higher ground than the well?		
3.	Is there any other source of pollution (e.g. animal excreta, rubbish)within 10 m of the well?		
4.	Is the drainage poor, causing stagnant water within 2m of the well?		
5.	Is there a faulty drainage channel? Is it broken, permitting ponding?		
6.	Is the wall (parapet) around the well inadequate, allowing surface water to enter the well?		
7.	Is the concrete floor less than 1m wide around the well?		
8.	Are the walls of the well inadequately sealed at any point for 3M below ground?		
9.	Are there any cracks in the concrete floor around the well which could permit water to enter the well?		
10.	Are the rope and bucket left in such a position that they may become contaminated?		
11.	Does the well require a cover?		
12.	Does the installation require fencing?		
	Total Score of Risks	**...…../12**	

Key: Contamination Risk Score: 9–12 Very high; 6–8 High;3–5 Intermediate; 0–2Low

Part III: Results and Recommemndations

The following important points of risk were noted:................................(List nos 1–12)

and the authority advised on remedial action.

Signature of sanitarian(Researcher)..

Siting of Wells in Relation to Latrines;

a) Location of shallow well in relation to latrine:

Downhill{ } Uphill{ } Relatively Flat Ground{ }

b) Gradient between the well and the cattle pen (If Any):

Downhill{ } Uphill{ } Relatively Flat Ground{ }

Human Hygiene and Sanitation Practices;

a) Human feces present within 10M around the shallow well

Present { } Absent { }

b) Animal droppings present within 10M around the shallow well

Present{ } Absent { }

Well Protection Status;

Protected { } Unprotected { }

If protected above, check for the following construction elements;

a). Damage to/lack of a concrete plinth Yes { } No { }

b). Breaks/Cracks in the parrapet wall Yes { } No { }

c). Breaks/Cracks in the cover (top) slab Yes { } No { }

d). Breaks in the drainage channel Yes { } No { }

e). Well area fenced out Yes { } No { }

f). Well covered while not in use; Yes { } No { }

THANK YOU!

APPENDIX IV: WATER SAMPLE COLLECTION FORM

WELL CODE…………………..

PART I: SAMPLING GENERALINFORMATION

1. Name of sub-location……………………………………………………...
2. Date Collected……………………………………………………..........
3. Time Collected……………………………………………………………
4. Date of Analysis………………………………………………………...
5. Time of Analysis………………………………………………………..

PART II: RESULTS
PHYSICAL PARAMETERS

1. Temperature at collection time…………………………………………….
2. pH at Collection Time…………………………………………………..
3. Turbidity……………………………………………………………………...

BACTERIOLOGICA PARAMETERS

1. **Total corliforms;** Present { } Absent{ } ……………………/100ml
2. **Fecal Coliforms;** Present { } Absent{ } ……………………/100ml
3. **Water Status Bacteriologically**

   Good{ } Bad{ }

Signature of Labaratory Technician………………………Date……………………….

Source: (Partly adapted from WHO, 1997)

THANK YOU!

APPENDIX V: SHALLOW WELLS SAMPLING PROCEDURE: ADAPTED FROM (WHO, 1997)

1. With a piece of clean string, attache a clean weight to the sterilized closed/corked sampling bottle.

2. Roll A 20-50M length of string around a stick and tie it to the bottle string.

3. Opened the sterelised bottle by carefully unscrewing the cap or pulling out the rubber stopper.

4. Lower the bottle weighed down by the weight, unwinding the string slowly without the bottle touching the sides of the well.

5. Immerse the bottle completely in the water without hitting the bottom of the well or disturbing any sediments.

6. Once the bottle is judged to be filled, carefully rewind the string on the stick to bring up the bottle and some water discarded to provide an air space.

7. Carefully recap/cork the bottle without touching the top and label the following information; date and time of sampling, then place in a cooler box ready for transportation. Repeat the above procedure for each and every grab sample to be collect with fresh sterilized bottles and weight to eliminate the possibility of contamination by previous samples.

APPENDIX VI: APPROVAL OF RESEARCH PROPOSAL

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kubps@yahoo.com
dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Internal Memo

FROM: Dean, Graduate School **DATE:** 17th May, 2016

TO: Mr. Oluoch E. Odiwuor **REF:** Q139/25993/13
C/o Department of Environmental & Population Health
KENYATTA UNIVERSITY

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that Graduate School Board at its meeting of 27th April, 2016 approved your Research Proposal for the M.Sc. Degree, Entitled **"Determination of Fecal Contamination Status of Shallow Wells in Dede Division, Migori County, Kenya".**

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

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

Thank you.

KENYATTA UNIVERSITY OFFICE OF DEAN 17 MAY 2016 GRADUATE SCHOOL P.O. BOX NAIROBI

REUBEN MURIUKI
FOR: DEAN, GRADUATE SCHOOL

c.c. Chairman, Department of Environmental & Population Health

Supervisors:

1. Dr. Daniel Akunga
C/o Department of Environmental & Population Health
KENYATTA UNIVERSITY

2. Dr. Jackim Nyamari
C/o Department of Environmental & Population Health
KENYATTA UNIVERSITY

RM/cao

APPENDIX VII: NACOSTI AUTHORIZATION

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 3310571, 2219420
Fax: +254-20-318245, 318249
Email: dg@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. **NACOSTI/P/16/83666/13255**

Date: **7th September, 2016**

Oluoch Evance Odiwuor
Kenyatta University
P.O. Box 43844-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Determination of fecal contamination status of shallow wells in Dede Division, Migori County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Migori County** for the period ending **6th September, 2017.**

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

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

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Migori County.

The County Director of Education
Migori County.

National Commission for Science, Technology And Innovation Is ISO 9001:2008 Certified

APPENDIX VIII: NACOSTI PERMIT

THIS IS TO CERTIFY THAT:
MR. OLUOCH EVANCE ODIWUOR
of KENYATTA UNIVERSITY, 226-40404 RONGO,has been permitted to conduct research in *Migori County*

on the topic: *DETERMINATION OF FECAL CONTAMINATION STATUS OF SHALLOW WELLS IN DEDE DIVISION, MIGORI COUNTY, KENYA*

for the period ending:
6th September,2017

Permit No : NACOSTI/P/16/83666/13255
Date Of Issue : 7th September,2016
Fee Recieved :Ksh 1000

....
Applicant's Signature

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

APPENDIX IX: RESEARCH AUTHORIZATION

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kubps@yahoo.com
dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 8710901 Ext. 57530

Our Ref: Q139/25993/13

Date: 17th May, 2016

Director General,
National Commission for Science, Technology & Innovation,
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MR. OLUOCH E. ODIWUOR REG. NO. Q139/25993/13

I write to introduce Mr. Odiwuor who is a Postgraduate Student of this University. He is registered for M.Sc. degree programme in the **Department of Environmental & Population Health in the School of Public Health.**

Mr. Odiwuor intends to conduct research for M.Sc. Degree thesis entitled **"Determination of Fecal Contamination Status of Shallow Wells in Dede Division, Migori County, Kenya".**

Any assistance given will be highly appreciated.

Yours faithfully,

KENYATTA UNIVERSITY OFFICE OF DEAN 17 MAY 2016 NAIROBI BOX 43844-00100

MRS. LUCY N. MBAABU
FOR: DEAN, GRADUATE SCHOOL

RM/cao

APPENDIX X: ETHICAL APPROVAL

KENYATTA UNIVERSITY
ETHICS REVIEW COMMITTEE

Email: chairman.kuerc@ku.ac.ke
secretary.kuerc@ku.ac.ke
ercku2008@gmail.com
Website: www.ku.ac.ke

P. O. Box 43844 - 00100 Nairobi
Tel: 8710901/12
Fax: 8711242/8711575

Our Ref: KU/R/COMM/51/772

Date: 1st July, 2016

Evance Odiwuor Oluoch
Kenyatta University,
P.O Box 43844,
Nairobi

Dear Oluoch,

APPLICATION NUMBER PKU/530/I622 – "DETERMINATION OF FECAL CONTAMINATION STATUS OF SHALLOW WELLS IN DEDE DIVISION, MIGORI COUNTY, KENYA."-VERSION 2

1. IDENTIFICATION OF PROTOCOL

The application before the committee is with a research topic, **"Determination of fecal contamination status of shallow wells in Dede Division, Migori County, Kenya."** –Version 2.

2. APPLICANT

Evance Odiwuor Oluoch, Department of Environmental & Population Health

3. SITE

Dede Division, Migori County, Kenya

4. DECISION

The committee has considered the research protocol in accordance with the Kenyatta University Research Policy (section 7.2.1.3) and the Kenyatta University Ethics Review Committee Guidelines **AND APPROVED that the research may proceed for a period of ONE year from 1st July, 2016.**

5. ADVICE/CONDITIONS

i. Progress reports are submitted to the KU-ERC every six months and a full report is submitted at the end of the study.
ii. Serious and unexpected adverse events related to the conduct of the study are reported to this board immediately they occur.
iii. Notify the Kenyatta University Ethics Committee of any amendments to the protocol.
iv. Submit an electronic copy of the protocol to KUERC.

When replying, kindly quote the application number above.
If you accept the decision reached and advice and conditions given please sign in the space provided below and return to KU-ERC a copy of the letter.

KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE OFFICE OF THE CHAIRMAN P. O. BOX NAIROBI
01 JUL 2016

DR. TITUS KAHIGA
CHAIRMAN ETHICS REVIEW COMMITTEE

I EVANCE ODIWUOR O. accept the advice given and will fulfill the conditions therein.

Signature…………………… Dated this day of 02/07/2016 …….. 2016.

cc. Vice-Chancellor
DVC-Research Innovation and Outreach