PREVALENCE OF DIARRHEA AND STATUS OF WATER USEDBY HOUSEHOLDS OF BANDANI INFORMAL SETTLEMENT IN KISUMU COUNTY, KENYA

BY

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DECLARATION

This research theses is my original work and has not been presented for any award in any other university or college.

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DEDICATION

This research thesis is dedicated to my family members and professional colleagues

ABSTRACT

The heaviest burden of diarrhea is borne by low-income populations with poor access to safe water and sanitation. In 2017, 11.80% of the total deaths were due to diarrheal diseases in Kenya. In Kisumu County, diarrhea is ranked second after HIV and AIDs as the main cause of deaths. The 2017Geographical Information System mapping of diarrhea per county indicated that Kisumu has a high incidence of diarrhea, with the informal settlements of Bandani reported to be the most highly affected. This study sought to assess the prevalence of diarrheal and status of water used by households of Bandani informal settlement. The specific objectives were to determine the prevalence of diarrhea that occurred within the past two weeks amongst the households of Bandani settlements, to assess the status of water used by households of Bandani settlements, to determine if a relationship exists between the status of water used in households and the prevalence of diarrhea amongst the households of Bandani settlements. This was a cross-sectional study where 115 of the 5164 households in Bandani were assessed using WHO formula for household surveys. The instruments for data collection were pretested household questionnaires and observation checklist. Water samples were collected and analyzed following the Water Services Regulatory Board's guidelines. The data demonstrated a positive, statistically significant association between the presence of contaminated water in homes and prevalence of diarrhea. The prevalence of diarrhea was 40%. Water vendors were the main source of water (28.6%), followed by wells (26.1%), and taps (22.6%).Water samples that were contaminated were 42.6%. Diarrhea episodes were higher when the main water source was vendors (48.9%) compared to a tap (38.2%), well (37.5%) and other sources (32.4%) but not statistically significantly ($P>0.05$). The prevalence of diarrhea episodes was higher in homes with bacterially contaminated water (50.8%) compared to clean water (31.8%) statistically significantly ($\chi 2=5.601$, $p=0.018$, $DF=2$). This study provides a reference point on water status, diarhea and their relationship in the informal settlements. The study concludes that diarrheal episodes were statistically and significantly higher in homes with bacterially contaminated water, the prevalence of contaminated water in households was high, and the prevalence of diarrhea episodes in households was high. I recommended that the population must be sensitized on the economical and health impact of status of water used by the households and their relationship with diarrhea.

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LIST OF ACRONYMS AND ABBREVIATIONS

APHA	:	American Public Health Association
APHRC	:	African Population and Health Research Centre
DALYS	:	Disability Adjusted Life Years
DHS	:	Demographic Health Survey
EPA	:	Environmental Protection Agency
EPHC	:	Environment Protection and Heritage Council
KDHS	:	Kenya Demographic Health Survey
KHSSP	:	Kenya Health Sector Strategic Plan
KIWASCO	:	Kisumu Water and Sewerage Company
KMFRI	:	Kenya Marine and Fisheries Research Institute
KNBS	:	Kenya National Bureau of Statistics
NDDI	:	National Digestive Diseases Information Clearing House
UN	:	United Nations
UNCHS	:	United Nations Conference on Human Settlement
UNICEF	:	United Nations Children's Fund
USEPA	:	United States Environmental Protection Agency
WHO	:	World Health Organization
WASREB	:	Water Services Regulatory Board
WRC	:	Water Resources Commission
WRI	:	World Resources Institute
WSSCC	:	Water Supply and Sanitation Collaborative Council

DEFINITION OF OPERATIONAL TERMS

Anthropogenic activities: Refers to an effect or object resulting from human activity, and in the context of pollution broadly applies to all major human impacts on the environment. The activities of concern are poor human waste disposal and urbanization resulting in unplanned rapid population growth.

Bacterially contaminated water: This is water sample that tests positive to the *E. Coli* bacteria. It was assessed based on culture of water that tested positive to the *E. Coli* bacteria. If it has bacterial contaminants, the color may or may not be clear as clean potable water. This was according to the WASREB standards of water contamination

Diarrhea: Diarrhea is defined by the WHO as the passage of three or more loose or liquid stools per day, or more frequently than is normal for the individual (WHO, 2016a). Acute diarrhea occurs for a day or two. The tendency of passing less formed stool than normal, is not diagnosed as diarrhea, same as passing loose, pasty stools in breastfed babies is not considered as diarrhea (NDDI, 2013). For this research, diarrhea was reported by the household heads after the definition was shared with them explicitly. We adopted the WHO definition.

Escherichia coli: This is a Gram-negative, rod-shaped bacterium, commonly found in the intestine of warm-blooded animals (endotherms). Unlike the general coliform group, *E. coli* are almost exclusively of fecal origin and their presence is thus an effective confirmation of fecal contamination.

Household: People who live together and share the same pot. In this study, the household was be represented by a household head.

Contaminated water: Assessed by testing water using chemicals to indicate the presence of E.Coli which is universally accepted as a maker of contamination.

Potable water: This is water of sufficient quality to serve as drinking water.

Prevalence of diarrhea: is determined by assessing the total number of households who reported presence of loose stool 3 – 4 times a day the previous two weeks out of the whole population sampled.

Pollution point source: Is a single identifiable localized source of water pollution.

Quality: A measure of excellence or state of being free from defects or impurities.

Sources of water: Sources of water were derived from previous studies on water which indicate adopted from studies donein Langas Estate, Eldoret and Mathare, Nairobi with similar household demographic information (Belachew, 2012; Elizabeth Wambui Kimani-Murage, 2007b)

Status of water The status of water is defined by the Environmental Protection Agency to include properties of water in a geographical area. It is a combination of the factors of source and quality of water within a geographical area at a given time. In this study the characteristics of water either being bacterially contaminated or not was used in combination to the source of water (UNEP/WHO, 1996).

Total coliform bacteria: These are rod-shaped, Gram-negative, non-spore forming bacteria which can ferment lactose with the production of acid and gas when incubated at 35-37°C. Total coliforms are universally present in large numbers in human feces. The presence of these bacteria in water is an effective confirmation of fecal contamination.

Waste: Refers to all unwanted materials disposed by humans and may include solid material and liquid substances such as sewage and waste water from household cleaning activities.

Water Quality: Is the chemical, biological and physical characteristics of water, and is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. In this study, bacterial water quality is of chief concern

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Accessibility to potable water is a fundamental right for dignity and well-being (UN- Water, 2021). More than 1.1billion people lack access to safe drinking water, this is particularly true in the Sub-Saharan Africa and South East Asia regions (SDG – 6). In the year 2015, diarrhea caused over 1·3 million deaths globally, while 1.7 billion cases were reported in households (GBD Mortality and Causes of Death Collaborators, 2017). Diarrhoea caused 71·59 million DALYs and was a leading cause of DALYs because of its disproportionate impact on young children (GBD Diarrhoeal Diseases Collaborators, 2017). The heaviest burden of diarrhoea is born by low-income populations with poor access to safe water, sanitation, and urgent medical care (GBD Diarrhoeal Diseases Collaborators, 2017). In 2015, diarrheal disease caused 33,224 deaths, translating in to 11% of the total death in Kenya(WHO, 2018). The Age-adjusted death rate due to diarrheal diseases in Kenya is 127.36 per 100,000 of population, ranking Kenya fifth worldwide in diarrheal deaths (Kenya Demographic health profile,2017; WHO 2018). In Kisumu county, a health survey conducted in 2014 indicated that 15% of the households reported diarrhea in two weeks preceding the survey(Kenya National Bureau of Statistics, 2014).

The Geographical Information System (GIS) mapping of diarrhoea per county by Ministry of Health from 2017indicated that Kisumu City had a high incidence of diarrheal diseases, with the informal settlements of Bandani reported to be the most highly affected(M.O.H, 2018).This survey indicated that the clustering of dysentery was denser in Bandani than in the other informal settlements. In 2016, the DHIS reported that Kisumu County had 67040 confirmed cases of diarrhea of which Kisumu West sub County and Kisumu East sub county comprised the highest proportions with 8238(12%) and 8136 (12%) in the two sub Counties respectively, the highest in the County. In Kisumu County, diarrhea is ranked second after HIV/AIDs as the main cause of deaths. Diarrhoea is also ranked the second cause of death in Kisumu West and Kisumu East sub counties in 2016(DHIS, 2016).

Unsafe water is a leading risk factor for diarrhoea. For example, in 2015, unsafe water was reported to be responsible for 61·1 million DALYs, comprising 85·4% of diarrheal DALYs globally (GBD Diarrhoeal Diseases Collaborators, 2017). Contaminated water used by households results in a total of 2.2 million deaths annually for children and adults, mostly in the developing world (WHO, 2013a).While SDG Target 6.1 aims at achieving universal and equitable access to safe and affordable drinking water for all by 2030 (United Nations Sustainable Development Goals, 2015), worldwide 3 out of 10 lack safely managed water services (“UNICEF, 2018). In Africa, for example, of the 47 countries, only 5 (10%) had over 10% of the proportion of population using safely managed drinking-water services by 2015 (World Health Organization, 2018). Contaminated water results in over 2000 deaths daily in Africa (United Nations Commission for Africa, 2015). In Kenya, by 2015, the proportion of population using safely managed drinking-water services was less than 6%, about 7 times lower than that of Cote d Ivoire, with 46% of population using safely managed drinking water, and the highest in Africa (World Health Organization, 2018).

Anthropogenic activities and rapid urbanization has led to increased occurrence of water pollution; industrial effluents and sewerage treatment water are discharged into rivers that flow close to human informal settlements (Belachew, 2012; Moumié Maoulidi, 2010). This is experienced in Bandani informal settlements where the River Kisat drains both industrial and the Kisumu County sewerage treatment plant’s effluents (Odoyo, 2014).

This study focused on the point of use bacterial status of water to elaborate its association with diarrheal disease incidence at household level. The main objective of this study is to assess the prevalence of diarrheal diseases and bacteriological contamination of water used by households of Bandani informal settlement in Kisumu West sub county, Kisumu County, Kenya in relation to the sources of water. There have been intervention studies that try to reduce the impact of diarrheal diseases. Most of the interventions had a similar degree of impact. However, the water quality interventions at the point of use were found to be more effective in a systematic review and meta-analysis of previous data from less developed countries (Fewtrell L, 2005).

International practice requires that drinking water be routinely examined to ensure its safety for drinking according to the set framework (EPA, 2015; Government of Kenya, 2012), implementation of these guidelines may not be possible especially in informal settlements like Bandani. The ever increasing cases of diarrhea especially in most of the informal settlement in

Kenya accessing piped water and water from wells are worrying, attesting to lack of or inadequate research on bacteriological status of these types of water. Multiple regular reports on diarrheal outbreaks have been produced by the WHO ("Cholera, Diarrhea and Dysentery update 2008," 2008; Moumié Maoulidi, 2010; WHO, 2013b); the most affected areas in Kenya are in Western region. Kisumu East District's informal settlements of Bandani are mentioned in these reports updating on recent reemergence of diarrheal diseases ("Cholera, Diarrhea and Dysentery update 2008," 2008; Moumié Maoulidi, 2010; WHO, 2013b). Studies to assess the quality of water used by households in informal settlements have been carried out in Punjab, Nairobi and Eldoret (Anwar MS, 1999; Belachew, 2012; Elizabeth Wambui Kimani-Murage, 2007b). A recent study in Bandani assessing the factors influencing access to safe water reported that 75% of the population was using contaminated water, this was attributed to the anthropogenic activities and the close proximity of the latrines to the water sources (Ochieng', 2011). The present study seeks to assess the bacteriological contamination status of water used in households of Bandani informal settlement. Bandani informal settlement is of more concern due to its proximity to the water sewerage treatment site and the Kisat River which may act as another source of contaminants for tap water in cases of pipe leaks (Odoyo, 2014).

1.2 Statement of the Problem

It is estimated that each year there are 1.3 to 4.0 million cases of diarrhea and 21,000 to 143,000 deaths globally due to diarrhea.(Ali, Nelson, Lopez, & Sack, 2015).In Sub-Saharan Africa, it is estimated that 1.8 million people die annually due to diarrheal diseases (Demissie, Yeshaw, Aleminew, & Akalu, 2021). The Geographical Information System (GIS) mapping of diarrhoea per county by Ministry of Health from 2017 indicated that Kisumu City has a high incidence of diarrheal diseases, with the informal settlements of Bandani reported to be the most highly affected (M.O.H, 2018). Besides, according to health data obtained from the health facilities in Bandani informal settlement, 2 in every 5 patients seeking medical help were suffering from diarrheal disease (Kenya Demographic and Health Survey, KDHS(2018). This implies that the heaviest burden of contaminated water is borne by low-income populations, especially those living in informal settlements, with poor access to safe water, sanitation, and urgent medical care. In Bandani informal settlement, the population living in the informal settlement and using unsafely managed water sources is high and so, the exposure to endemic gastrointestinal disease among this population is enhanced. While it is largely documented by many scholars that people living in informal settlement don't access safe drinking water, there is scanty of empirical evidence that shows the level of bacterial contamination of water used by households of informal settlements, rate of diarrheal diseases and the relationship between episodes of watery diarrhea, sources of water and the bacterial contamination of water used in households. Therefore, this study seeks to determine the prevalence of bacterial contamination of water and occurrence of diarrheal disease among the households of Bandani informal settlement in Kisumu West Sub County.

1.3 Study Objectives

1.3.1 Main Objective

The main objective of this study is to assess the prevalence of diarrheal and status of household water used by households of Bandani informal settlement in Kisumu West sub county, Kisumu County, Kenya in relation to the sources of water.

1.3.2 Specific Objectives

i. To determine the prevalence of diarrhea in households of Bandani informal settlements in Kisumu West Sub County
ii. To identify the sources of water used by households of Bandani informal settlements in Kisumu West Sub County.
iii. To determine the proportion of households with bacterially contaminated water in Bandani informal settlements in Kisumu West Sub County.
iv. To determine the association between prevalence of diarrhea and the status of water used in households of Bandani informal settlement

1.4 Research Questions

i. What is the prevalence of diarrheal in households of Bandani informal settlements?
ii. What are the sources of water used by households in Bandani informal settlements?
iii. What percentage of the households in Bandani informal settlements use water that is contaminated by bacteria?
iv. What is the association between the prevalence of diarrhea and status of water used in households of Bandani informal settlement?

1.5 Justification

Tap water and the communal well water points are the main sources of water for domestic use among the inhabitants of Bandani informal settlement in Kisumu City. This region is witnessing population increase due to rural urban migration and there are many episodes of diarrheal disease outbreaks recently. The population increase has also increased anthropogenic activities that contribute to the discharge of large quantities of waste. With inadequate sewerage treatment facilities and poor waste disposal practices in this area, there is deterioration of the water used by households for drinking and other domestic uses. It has households located in plots averaging about an eighth of an acre(*Kenya population and health census*, 2019). A plot can have up to thirty households, each household having an average of six occupants. Their water is sourced from communal water points which are either taps or wells. They share pit latrines which are in close proximity to the water points and houses due to the small sizes of the plots(*Kenya population and health census*, 2019). It is one of the most commonly affected areas in Kisumu West District with diarrheal disease outbreaks. The multiple WHO outbreak reports regularly mention Bandani informal settlements (WHO/UNICEF, 2014). Kisat River is on the Eastern border of Bandani Settlement. Kisat River is full of industrial effluents from the industrial area and effluents from the sewerage treatment plant located along its banks.

Airport Health Centre is the nearest government health facility. The facility records show that the leading cause of mortality is HIV and related complications, followed by Diarrhea and related complications (DHS 2021). Bandani Informal settlement is in Kisumu West Sub County which ranks first in the incidence of Diarrhea in the county among other sub counties (DHS 2020).

The status of water in this area may be an exposure factor to diarrheal diseases. There is no clear information on the proportion of bacterial contamination, the frequency of watery diarrhea in households in relation to the level of contamination in households or other household factors. Water from wells may be contaminated due to anthropogenic activities including close proximity of water points to latrines and human waste disposal areas, while tap water could be affected by the contaminants into the pipes due to poor plumbing. This study, therefore, seeks to assess the bacteriological status of the water used by inhabitants of Bandani informal settlements in Kisumu City. The study is to provide a relationship between the level of contamination at that point in time and a history of diarrheal disease episodes, other hygiene practices and other household specific factors. The study findings can provide an important source of information for policy makers and other public health stakeholders. It will also provide a public health advocacy approach to water and sanitation problem that affects the urban poor. It will provide a reference point on waste management, diarrheal disease outbreaks, water quality improvement and water quality maintenance.

1.6 Scope of the study

This study was confined to assessing the prevalence of diarrhea and its relationship to the sources and bacterial contamination of water by the households of Bandani Informal Settlement scheme using self-reported cases of watery diarrhea that occurred within the past two weeks in a household survey, at the point of use, conducted during the month of August to September 2018.

1.7 Limitations of the Study

Being a cross sectional design, there is a limitation of recall which was corrected by shortening the duration of recall. Another possible limitation is the use of questionnaire to probe about some relatively private and embarrassing details like occurrence of diarrhea in the household. This was sorted by reassuring the respondents of maximum confidentiality in the data collection and utilization process. The researcher also explained to them the purpose of the study in the consent form. Another limitation is that we did not have the ability to have a follow up data to confirm or reject our hypotheses. This will be covered by a recommendation to have a follow up research in one or two years.

1.8 Conceptual Framework

The bacterial contamination of water used in households and the resultant diarrheal disease occurrence is determined by both natural and anthropogenic activities. However, of greater influence are the anthropogenic activities; these include plumbing defects on tap waters, construction of latrines close to shallow wells, poor storage of water within the household, ignoring the importance of treatment of water before drinking and open defecation. The natural factors that can lead to bacterial contamination of water are rain water destruction of water pipes, livestock activities, topography of an area relative to the position of shallow water wells, and natural disasters that can lead to contamination. Other factors that may affect the results of the study include the ability of the respondent to identify and remember episodes of diarrhea in the household. It is important that as we seek to know the bacteriological status of water used in households and relate it to the diarrheal episodes in two weeks, we should consider these dependent and independent variables as presented in the diagram below.

INDEPENDENT VARIABLES

- Water sources:-taps, wells, springs, rainwater, streams, lake and rivers
- Contamination of water at the source

DEPENDENT VARIABLE

- Status of water
- Prevalence of diarhea

Figure 2.1: Conceptual Framework

Adopted (Anwar MS, 1999)

CHAPTER TWO

LITERATURE REVIEW

2.1 Diarrheal Disease Occurrence

Diarrhea is defined by the WHO as the passage of three or more loose or liquid stools per day, or more frequently than is normal for the individual (WHO, 2016a). Acute diarrhea occurs for a day or two. The tendency of passing less formed stool than normal, is not diagnosed as diarrhea, same as passing loose, pasty stools in breastfed babies is not considered as diarrhea (NDDI, 2013). Diarrheal infection is spread through contaminated food or drinking water due to poor hygiene according to the World Health Organization report, 2016(WHO, 2016a). The same report states that in the sub-Saharan Africa, a child suffers five episodes of diarrhea annually. The annual mortality from diarrhea in children less than five years old in developing countries is 1.8 million deaths per year with 800,000 occurring in Sub Saharan Africa; WHO, 2016a).

In Kenya, although major facility – and community – based interventions strategies have been implemented to improve access to effective preventions and treatments of diarrheal cases, however, the burden of diarrheal is still substantial(Ali et al., 2015; Guillaume, Justus, & Ephantus, 2020). In the year 2018, 1,499,146 cases of diarrhea were reported among children under five years (Guillaume et al., 2020)

Studies have been done before to determine the occurrence and risks of diarrheal diseases in settlements of similar status. In Ethiopia, it was found that children living in households with some form of toilet facility are less likely to be affected by diarrheal diseases than those that do not have these facilities (Yohanness AG, 1992). Lack of a toilet facility was associated with a high incidence of diarrhea (Boadi KO, 2005; Levine OS, 1991). The greatest reduction is associated to flush toilets than the pit latrines. This was related to the presence of houseflies in the pit latrines that could lead to the transportation of contaminants to human food and water (Levine OS, 1991). In both studies, the level of education of the parent was found to play an important role in the determination of diarrheal prevalence. A higher education level was found to be associated with lower prevalence. The study to be conducted in Bandani settlements is similar to these studies in the aspect of determining the occurrence of diarrheal diseases per household. It will also seek to assess the educational level of the parents and link it to the frequency of diarrheal episodes within their households.

The bacterial status of water is a key predictor of its diarrhea causing pathogenicity. It is accepted by public health regulatory bodies that bacterial indicators can be used to determine the level of contamination of water (WHO, 2000b). The report further stressed the importance of diarrheal diseases caused by water contamination as the number four cause of mortality worldwide. The burden is more in the developing world than in the developed world. Preventive model studies by WHO and UNICEF in 2014 showed that high coliform counts are found in most waters used in the rural areas and informal settlements in urban areas, and that human waste remains the largest source of contamination of water masses (WHO/UNICEF, 2014). Multiple species of bacteria can be isolated in drinking water that is contaminated. However, the American Public Health Association stated that the presence of coliforms in water is a sure sign of contamination and bacterial pathogenicity of water (American Public Health Association, 2014). Further, treatment of water before drinking is a major way of reducing waterborne diseases. It is stated as an important public health advancement of the twenty first century (Centers for Disease Control and Prevention, 1999).

2.2 Bacterially Contaminated Household Water

The pathogens that are widely recognized to cause dangerous waterborne diseases by public health professionals are *Salmonella typhi*, *Vibrio cholerae*, *Shigella* and pathogenic *E. coli*. Waterborne diseases are typically caused by enteric pathogens which belong to the group of organisms transmitted by the fecal-oral route (Cabral, 2010). Most waterborne pathogens are distributed worldwide, but outbreaks of some, for instance cholera and typhoid, tend to be regional. The main goal of drinking water treatment is to remove or kill pathogenic organisms in order to reduce the risk of illness (Frank R. Spellman, 2012).

The bacteria in water cannot be completely eliminated yet some bacteria have been reported by previous studies to be pathogenic (Vikaskumar G. Shah, 2007; Zamxaka M, 2004). The common bacteria in water are the Coliforms including *E. coli,* its presence is a sign of fecal contamination of the water and therefore, it has a maximum contaminant level (MCL) measure of 0.00% according to the USA Environment Protection Agency(EPA, 2015).

Although coliforms are not usually pathogenic themselves, their presence in drinking water indicates the possible presence of pathogens (EPA, 2002). *Escherichia coli*, one of the coliform groups is always found in feces and is, therefore, a more direct indicator of fecal contamination and the possible presence of other enteric pathogens (EPA, 2015). For many decades, public health officials and researchers have evaluated water quality by enumerating fecal coliforms and *E. coli* levels in waters (Malakoff, 2002; Pandey PK, 2012). This study seeks to add to the existing pool of data with a focus on the urban poor who are sometimes not formally considered in water quality monitoring campaigns.

However, in a study done in Kisumu County's Nyakach plateau, hydrogen sulphide producing bacteria were isolated from the water used by the households; they were specifically Edwardsiella, Citrobacter, Salmonella, Proteus, and Klebsiella (Bruce, 2014). The study sampled water in bottles from the sources commonly used by the villagers; they concluded that the water was polluted by bacteria and other pollutants. Just like the study in Nyakach plateau, this study involved the lower middle class and the low class citizens who depend on communal water points. However, this study also explored on the sources of bacterial contamination, the proportion of water that has bacterial contamination from different households and the aspect of frequency of diarrheal diseases occurrence was also be highlighted guided by the global public health principles. Our study also collected samples using sterilized bottles for further analysis. The major pathogenic organisms responsible for household water contamination are bacteria; *E Coli, Shigella, and V cholerae*, viruses; *Hepatitis A, Polio Virus, and Rota Virus* and parasites; *E histolytica, Giardia, Hook worm* (Stefano Guandalini, 2015).

2.3 Sources of Water Contamination

Inadequate water supply in informal settlements is one of the major risk factors for diarrheal disease, a leading cause of mortality and disability – adjusted life – years (DALYs) globally (Sinharoy, Pittluck, & Clasen, 2019). According to WHO/UNICEF joint Monitoring Programme for Water Supply, 844 million people globally still lack a basic drinking water services(Organization, 2017). This more compounded in people who leave in informal settlements (Govender, Barnes, & Pieper, 2011). And where water supply may exists, access may be uneven and availability may be intermittent(Pierce, 2017). Research has shown that intermittent water supply is associated with lower microbial quality and high risk of diarrhoeal diseases; this results in households storing water which can introduce contamination (Bivins et al., 2017)Water sources is an important factor indicator of community health (Nguyen et al., 2021). A study by (Aguilar-León & Solano-Zapata, 2016) found out that inhabitants in informal settlements are not authorized to have private water connections to their homes due to high population densities making separation of water supply and sewage difficult; however, some make illegal connections without any supervision or instruction for local municipality, thus creating a path for potential pollution. In another study by (Kapwata, Mathee, Le Roux, & Wright, 2018), they observed that informal settlements are constrained in terms of space and water supply, and most of communal sanitations facilities are not linked to sewage systems. Stagnant water is often observed in such dense informal communities, which poses risk of spreading diarrhea pathogens in the environment.

Furthermore, (Alegbeleye & Sant'Ana, 2020) suggested that not all water treatment methods are effective if carried out in an unhygienic manner, improper infiltration coupled with unsafe water storage facilities could led to recontamination after treating. Tap water may be exposed to less contaminant than the well waters. The contaminants for different water sources vary slightly. According to a study done in the Eldoret's Langas informal settlement, the sources of water contaminants are not always understood by the households of these settlements. This reduces the chances of prevention of water contamination by the households (Elizabeth Wambui Kimani-Murage, 2007a). The study further explained that due to the small sizes of the residential plots, the households are left with less than the recommended distance of twenty meters from a latrine to a well. Fecal contamination can easily seep into the water source causing contamination. Apart from noting the level of contamination of the water used by the households of our study area, the current study will go further to try and assess the relationship between the contamination in water and the diarrheal diseases in the area with an aim of informing the households on how to reduce the sources of contamination.

Bacterial contamination is a common problem in both the developing and the developed world. In a 2014 study in United Kingdom, the bacterial contamination of water was identified as a major factor affecting water quality, it was stated that environmental pollution was a major contributor. In the 19th century, the cities of Europe and North America were hit by multiple outbreaks of cholera and typhoid which were controlled, but in the developing world the outbreaks still exist("Facts on Drinking Water: Coliform Bacteria - Total Coliform and E. coli," 2004).

2.4 Relationship of drinking water and prevalence of diarrheal

Globally, drinking water has been established as a primary transmission pathway for diarrhea pathogens(Gruber, Ercumen, & Colford Jr, 2014) Research has shown that diarrheal diseases is correlated to unhealthy sanitation and poor sanitation (Prakoso, 2020). In developing countries, there is a large body of evidence that improving the microbial quality of drinking water by household treatment and safe storage reduces diarrhea (Prakoso, 2020). Previous meta-analysis of data from Africa have evaluated the evidence for the link between household drinking water quality, measured by fecal indicator organisms, however, the authors found no evidence of an association between diarrhea and indicators of drinking water contamination (EC, FC and *fecal streptococci*) (de Aceituno, Stauber, Walters, Sanchez, & Sobsey, 2012).

A recent study in Bandani assessing the safe water reported that 75% of the population was using contaminated water, the study further recommended research to find the relationship between the quality of water and occurrence of diarrhea. (Ochieng', 2011).

2.5 Summary of Literature Review

The water status is a combination of the sources of water and the contamination status. The status of water is defined by the Environmental Protection Agency to include properties of water in a geographical area. It is a combination of the factors of source and quality of water within a geographical area at a given time. In this study the characteristics of water either being bacterially contaminated or not was used in combination to the source of water (UNEP/WHO, 1996). Water quality is a key factor in the etiology of diarrheal diseases worldwide (Frank R. Spellman, 2012). Diarrhea causing pathogens are mostly transmitted through contaminated water and this is common in developing countries with rapid urbanization and increased informal settlements (Elizabeth Wambui Kimani-Murage, 2007a). An analysis showed that 46% of the world population is either not having a reliable source of water or they are having contaminated water (WHO 2017). This was translating to 1.7 billion people. The greatest percentage of those affected with poor status of water according to the WHO are in the developing world (WHO 2017). Contaminated water used by households results in a total of 2.2 million deaths annually for children and adults, mostly in the developing world (WHO, 2013a). While SDG Target 6.1 aims at achieving universal and equitable access to safe and affordable drinking water for all by 2030 (United Nations Sustainable Development Goals, 2015), worldwide 3 out of 10 lack safely managed water services(“UNICEF, 2018). In Africa, for example, of the 47 countries, only 5 (10%) had over 10% of the proportion of population using safely managed drinking-water services by 2015 (World Health Organization, 2018). Contaminated water results in over 2000 deaths daily in Africa (United Nations Commission for Africa, 2015). In Kenya, by 2015, the proportion of population using safely managed drinking-water services was less than 6%, about 7 times lower than that of Cote d Ivoire, with 46% of population using safely managed drinking water, and the highest in Africa (World Health Organization, 2018). A meta-analysis commissioned by the World Bank had findings showing that hygiene education and water quality improvements were more effective at reducing the incidence of diarrheal disease in Africa, (42 percent and 39 percent, respectively) than sanitation provision and water supply (24 percent and 23 percent, respectively) (Fewtrell & Colford, 2004).The informal settlements are more prone to water contamination due to the presence of numerous sources of water contaminants (Elizabeth Wambui Kimani-Murage, 2007b). Household water treatment is also important in the reduction of diarrheal disease incidence (Alekal, 2005). This study seeks to develop a review of the status of the water used, the methods of household water treatment, the possible sources of water contaminant and the occurrence of diarrheal diseases within households of Bandani; a place with regular diarrheal disease outbreaks without any prior studies on its water quality in relation to the outbreaks.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Introduction

The structure of the research questions sought out the provision of an informed evaluation of the prevalence of diarhea, the status of water and the association between the status of water and prevalence of diarhea in Bandani informal settlement. The study provides essential data to all the sectors involved in health, national development, and policy setting and implementation. The research dwelt specifically on households that live in this area.

3.2 Study Design

Thiswas a descriptive cross-sectional study in which the prevalence of watery diarrhea amongst the households of Bandani Informal Settlement Scheme was assessed using questionnaire; water samples collected from households were tested in the laboratory for bacterial contamination. The questionnaires were used to get information on the status of water used by the households. Observation forms were used to collect data on the anthropogenic activities that may affect the quality of water used by the households of Bandani informal settlement.

3.3 Instruments of Data Collection

The instruments that were used for data collection were questionnaires, observation checklist and testing of water for contamination.

3.3.1 Household Questionnaires

This study used semi-structured questionnaires (Appendix 3) and were administered to households of Bandani informal settlements. The household questionnaires was divided into three sections i.e, section A giving the demographic information of the respondents, section B determining the frequency of cases of diarrhea that occurred within the past two weeks amongst the households of Bandani informal settlements in Kisumu West Sub County, while section Cidentified the main sources of water used by households of Bandani informal settlements in Kisumu West Sub County. The questionnaire was written in English and translated to national language (Kiswahili) for easy understanding by the respondents.

3.3.2 Observation checklist

The study also used nonpartisan observations checklist to gather and document data related to sanitation and the proximity of the water points to possible contaminative anthropogenic activities. This would identify the sources of water and the safety of the sources of water.

3.4 Validity and Reliability of Research Instruments

3.4.1 Validity of the Instrument

Validity of research instrument refers to the extent to which a test or instrument measures what it is intended or supposed to measure (Mbwesa, 2006). This study adopted the triangulation approach so as to measure the validity of the instruments. Triangulation is a powerful way of demonstrating concurrent validity in both qualitative and quantitative research (Campbell and Fiske 1959). In other words, the study used multiple methods of data collection: interviews, questionnaires as well as observation checklist. By so doing, areas that had been overlooked by one method were strengthened and checked by the other. The cross-checking of data through multiple method approach made sure that the data collected was valid. This is in line with Cresswell (2009) who contends that the use of multi-model technique to data collection averts the possibility of having invalid and unreliable data.

To ensure that the data gathered measures what the study purported to measure, the research study further adopted content validity. Here the research instrument was scrutinized by the two supervisors to assert that the instrument logically appeared to reflect accurately what it purport to measure and cover what it is intended to cover (Mbwesa, 2006). The two supervisors read through the questions that were used in the study. The ones that were not be correct were rephrased and others modified. This helped the researcher to ensure that there is content validity of the instruments.

3.4.2 Reliability of the Instrument

3.4.2.1 Reliability of Research Instruments

Reliability according to Gall and Borg, (2007) refers to the degree to which similar results will be arrived at by other researchers if they use the same procedures. In this study, reliability of data was judged by estimating how well the items that reflect the same construct yield similar results. According to Connelly (2008), extant literature suggests that a pilot study sample should be

10%-30% of the sample projected for the larger parent study. Therefore, questionnaires were administered to 12households of Obunga informal settlements. With the aid of SPSS v. 22, reliability of the questionnaires was computed using Cronbach alpha reliability test. This was to test internal reliability of the tools. The Cronbach alpha test was good (0.8 = α).

The research instruments were pilot tested to establish their reliability. This was done among the households in Obunga informal settlement. This was because of similar demographic characteristics as the area of study. Simple random sampling was used to generate a sample size of 12 respondents which account for 10% of the parent sample size. According to Connelly (2008), extant literature suggests that a pilot study sample should be 10%-30% of the sample projected for the larger parent study. Therefore, questionnaires were administered to 12 households of Obunga informal settlements and interpretation of the response alternatives and queries was carried out to form items that bear the same meaning but are not identical. Order of response alternatives were similarly changed for questions with normal scale to assess the validity and reliability. Meanwhile, respondents' choices were evaluated for appropriateness. The questions were also verified to check if all the respondents understood them the same way. In addition, average time taken to complete the questionnaires was noted and the overall pilot test results were analyzed and adjustments made according to the results of the instruments review and pilot test prior to the production of the final instruments.

3.5 Study Population

Population means all elements and people who share one or some common quality in a special geographical scale. In addition, Babbie (2007) also describe a population as the total collection of elements whereby references have to be made. The study population were the household members of Bandani Informal settlement who were administered with questionnaires to provide quantitative information on objectives of the study.

3.6 Sample Size Determination

To determine the sample size, we adopted the WHO Guidelines on the Household Survey Manual for Diarrhoea and Acute Respiratory Infections (WHOs, 2002).

The calculation of the optimal sample size was broken down into a series of individual steps, as follows:

Number of households, n = [4 (r) (1-r) (f) (1.1)] / [(e2) (p) (nh)]

Where

n = the required sample size,

4 = a factor to achieve 95% level of confidence (i.e. a reflection of the degree of certainty of obtaining the same results if the survey were to be repeated),

r = the anticipated prevalence of the outcome being measured,

1.1 = a factor necessary to raise the sample size by 10% to allow for no responses,

f = the design effect,

e = the margin of error to be tolerated,

p = the proportion of the total population that the smallest subgroup comprises,

nh = the average household size.

When we substitute with our data we find that:

4 = the factor to achieve 95% level of confidence

r = 15.5%, this is the estimated prevalence of diarhea in the area of study

1.1 = factor necessary to raise the sample size by 10% to allow for non-responses

f = 1our design effect since we are using simple random sampling

e = 5%

p = 1, there is no sub group we are studying, the whole population of the household is studied.

nh = 2, the minimum household size in Kenya

thus:

n = [4 (0.155) (1-0.155) (1) (1.1)] / [(0.052) (1) (2)]

n = 115 households

According to equation (i) the study sample obtained was 115 respondents.

Simple random sampling was used to identify the households. The collection of the water samples for every household. Simple random sampling is chosen because it eliminates biasness as it gives every household head equal chance of being selected for the study.

3.7 Sampling Techniques

A sampling frame was created from the household list of 5164 serialized households. Random household numbers were selected from the sampling frame. The households that had the specific numbers were identified in terms of the specific location in the settlement. Consent was sought and the data collected from these households. This was a probability sampling technique whereby each household had an equal chance of being iced for the study.

3.8 Inclusion and Exclusion Criteria

3.8.1 Study Area

The study was carried out in Bandani Informal Settlement in Kisumu West Sub County, Kisumu County. Bandani informal settlements falls under the high density, low – income areas caused by the rapid industrialization and urbanization of Kisumu(*Kenya population and health census*, 2019). It is 3.5 Kilometers from Kisumu Central Business District. The geographical coordinates of the Bandani estate are -0°4'9''N 34°44'7''E. It has households located in plots averaging about an eighth of an acre(*Kenya population and health census*, 2019).

Inclusion criteria

1. The households that draw their water from the defined water sources.
2. The households that had at least two members one of them being an adult.
3. The water samples collected within less than one day

Exclusion criteria

1. Households that the household heads do not consent to the study
2. When the household head cannot confidently confirm the source of water for household use.
3. Households who have used the water for less than six months or have just moved to Bandani.
4. Passing of loose watery stool in breastfed babies.

3.9 Data Collection Procedure

Data was collected in a period of three weeks. All the communal water points were located and serialized accordingly. The tap water points were marked separately from the well water points. The community informants assisted in the location of all the water points on the first day of the study. On the day of data collection, the household heads assisted the research teams in locating the family's main water collection point. The household water storage point were also located for sample collection purposes. The samples we recollected aseptically using sterile water collection bottles. Each sample bottle was marked with the date of collection, the time of collection, and the point of collection. Equal quantities of 100 milliliters per household sampled were collected. They were stored in cooler boxes packed with ice packs and transported to the laboratory for immediate analysis. The samples were analyzed within twelve hours from the time of collection. Fecal contamination of the water was determined through isolation of indicator organisms, total coliforms, and then thermo tolerant (fecal) coliforms, through multiple-tube fermentation (MTF) technique. Probability tables (McCrady tables) were used to determine the Most Probable Number (MPN) estimates of the coliform organisms per 100 ml of water. Analysis of data was generally descriptive, involving determination of frequencies.

The household heads responded to a questionnaire after the water sample collection and identification of the water sources. Thereafter, the observational form was filled by the researcher.

3.10 Data Management and Analysis

The data capture screen was prepared based on the dependent and independent variables of the study. The data field incorporated the check codes in order to ensure quality data entry. Further, in the table below shows the objectives, the variables analysed and the data presentation used .Descriptive statistics were used to summarize the data characteristics, presented as frequency, percentages, means and standard deviations on non-transformed data. This analysis technique was used in determining the frequency of cases of diarrhea that occurred within the past two weeks amongst the household members of Bandani informal settlements in Kisumu West Sub County and identifying the main sources of water used by households of Bandani informal settlements in Kisumu West Sub County.

Objective	variables	Data collection analysis and presentation
To identify the sources of water used by households of Bandani informal settlements in Kisumu West Sub County.	Water sources:- Taps Wells Vendors Other sources	Data was collected using questionnaires and observational check list. Frequency tables, graphs and pie charts, were used to present the data. Chi square tests were done for analysis
To determine the prevalence of diarrhea in households of Bandani informal settlements in Kisumu West Sub County	Diarhea As reported by the household heads	Data was collected using the household questionnaire. Graphs, frequency tables and pie charts were used to present the data. Data was analyzed using statistical tests and descriptive statistics.
To determine the proportion of households with bacterially contaminated water in Bandani informal settlements in Kisumu West Sub County.	Status of water Contaminated water Not contaminated water	Thematic analysis was done after collection of water samples, and laboratory analysis to determine the contamination or non-contamination status. Data was presented in frequency tables. Chi square test was performed.
To determine the association between prevalence of diarrhea and the status of water used in households of Bandani informal settlement	Status of water and diarrhea	Data was collected using questionnaires, observational checklist, and laboratory reports on the water samples. Descriptive statistics were used to analyze and find relationships.

3.10.1 Water Analysis of Bacterial (E. coli) Causing Diarrhea

According to WASREB guidelines, the Water Act 2016 under Section 72 requires WASREB to determine and prescribe national standards for the provision of water services and asset development for water services providers and monitor compliance with standards including the design, construction, operation and maintenance of facilities for the provision of water services by the water works development bodies and the water services providers. Therefore, to collect water samples at household level, sterile plastic water bottles were used in collecting the water samples. The 125ml bottles were used to collect a 100ml of water per household. A total of 115 water samples were collected, with one water sample per household. Fecal contamination of the water was determined through isolation of indicator organisms, total coliforms, and then thermo tolerant (fecal) coliforms, through multiple-tube fermentation (MTF) technique. Probability tables (McCrady tables) were used to determine the Most Probable Number (MPN) estimates of the coliform organisms per 100 ml of water. Analysis of data was generally descriptive, involving determination of frequencies.

3.10.1.1 Storage and handling of water samples

The samples were stored in iced cool box to avoid contamination, and transported to the laboratory for analysis. The water sampling, preservation and tests was performed according to the Water Services Regulatory Board guidelines (WASREB, 2002).During the analysis, to protect against potential contamination/infection, water samples were stored in sterile bottles and sterile scooper was used to obtain the sample from the bottles. Moreover, the analysts wore hand gloves all through when handling the water samples.

3.10.1.2 Analysis of Bacterial (E. coli)

The standard plate count method was used to determine the E. coli counts. The methodology for the Petrifilm plates was used, but samples were passed through sterile 0.45-μm filters prior to incubation. Sample incubation involved inoculating and spreading 1 ml of water sample on the gel, then incubating the plates at of 35 °C for 24 hours, and counting the number of blue colonies associated with a small gas bubble. Cultures were enumerated by counting the number of blue colonies. This test was also used to determine the most probable number of E. coli per 100 ml of water in a household. The results was compared to the WHO (2010) drinking water standards so that it determines the bacterial contamination level of the water.

3.11 Ethical Considerations

This study commenced upon approval by Maseno University Ethics Review Committee (MUERC). Permission to carry out the study was sought from Maseno University School of Graduate Studies (SGS) after which a letter of authorization was acquired from the County Director of health, Kisumu County to get a nod to collect data from Bandani informal settlement. Study participants were taken through a consent form in a language that they understood and requested to participate willingly. No participants was forced to participate in the study, neither were they be unduly influenced.

The current study was be purely an academic research for Masters in Public Health in Maseno University. The research team observed the universal ethical principles, including respect for participants, beneficence and justice.

In regard to respect for participants, all participants gave consent after the researcher's explanation of the purpose of the study, its risks and benefits and that participation was voluntary. The participants were also informed of the right to withdraw consent at any time without any penalty. All information was kept confidential. The researcher also observed respect through asking questions that were be injurious to respondents' personality and dignity. Data collected were stored in soft copy and password protected in email and cloud for at least 5 years after completion (University of Virginia, 2012).

For beneficence, respondents were explained for the purpose of the study and that there was no direct monetary gain to them, only that the findings would benefit them through their sensitization and that of policymakers on the importance of water quality improvement and maintenance.

To ensure justice, respondents were assured that the information given were only used for the research purpose and treated with utmost confidentiality. Further, the respondents were asked not to indicate their names on the questionnaires to ensure the anonymity of their response. The information was sought in one on one contact at the respondent's house as this is a conducive environment.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics

A total of 115 household heads (56.5% males and 43.5% females) were interviewed (Table 4.1). The mean age of respondents was 34.61±10.11 years. Most respondents had attained college education (36.5%), were in formal or self-employment (64.3%) and had children in the household (90.4%)

Table 4.1: Socio-demographic characteristics of household heads in Bandani Settlement scheme, Kisumu West Sub County, 2020

		N (115)	**%**
Gender	Male	65	56.5
	Female	50	43.5
Age in years	Mean±SD	34.61±10.11	
Education	Primary	11	10.4
	Secondary	35	30.4
	College	42	36.5
	University	27	23.4
Employment	Employed	74	64.3
	Unemployed	41	35.7
Children in household	Yes	104	90.4
	No	11	9.6

4.2 Prevalence of diarrhea amongst the households of Bandani

Of the 115 households that were visited, 45 households (40%) indicated that they had experienced cases of watery diarrhea. However, only nine (19.5%) of the 45 households that reported cases of diarrhea needed hospitalization.

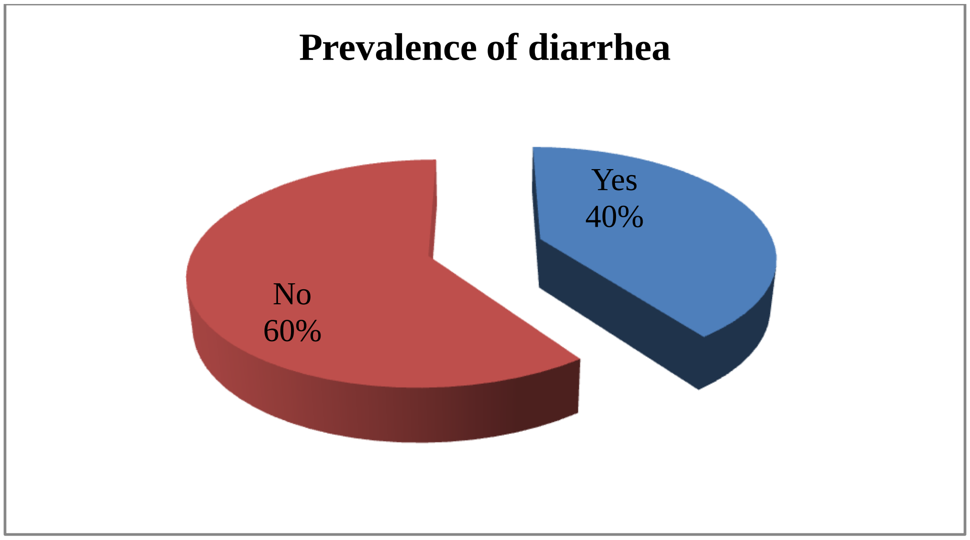

Figure 4.1: Household that reported the occurrence of diarrhea within the past two weeks in Bandani informal settlement scheme July 2020.

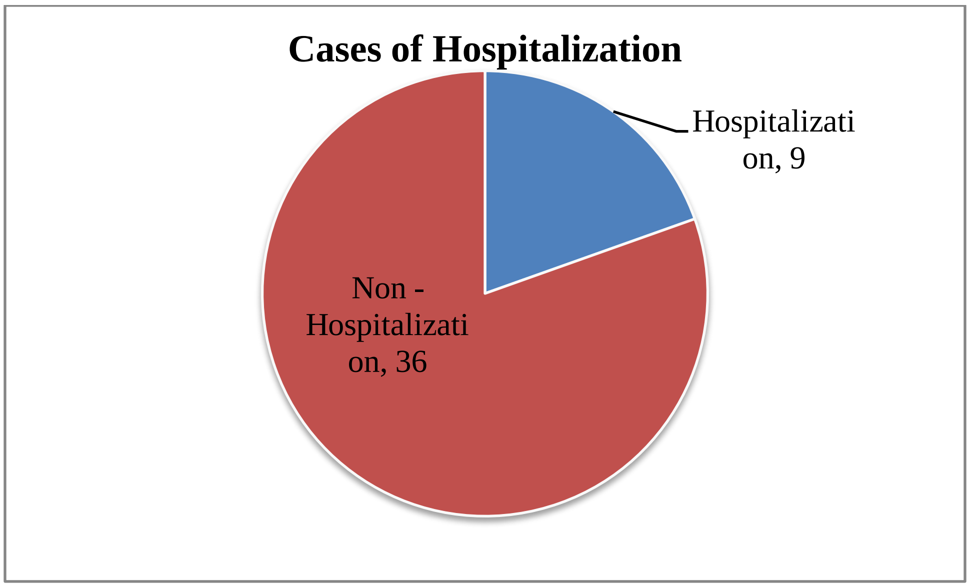

Figure 4.2: Cases that needed hospitalization from the households in Bandani Settlements

A comparison of the distribution of watery diarrhea amongst various socio demographic variables indicated that the frequency of watery diarrhea was significantly higher in households where household heads were unemployed (51.9%) compared to employed heads (33.3%), $\chi 2$ =4.998, P=0.025, and had children (42.4%) compared to no children (14.3%), $\chi 2$ =4.207, P=0.040. Gender of household heads and education of household were not associated with watery diarrhea episodes (P>0.05).

Table 4.2: Distribution of watery diarrhea by demographic characteristics of household heads

		Diarrhea episodes			
		Yes (45)	**No (69)**	**$\chi 2$**	**P value**
Gender	Male	12 (24.0%)	38 (76.0%)	0.316	0.574
	Female	34 (52.3.0%)	31 (47.7%)		
Education	Primary	2 (18.1)	10 (81.9)	3.908	0.272
	Secondary	15 (42.8)	20 (57.1)		
	College	20 (47.6)	22 (52.4)		
	University	9 (33.3)	18 (66.7)		

Table 4.3: Demographic information about Diarrhea episodes

Demographic factors		**Diarrhea episodes (n=45)**	
		Frequency	Percentage
Sex	Male	39	86.7%
	Female	6	13.3%
Age category	19 - 29	18	40.0%
	30 - 39	12	26.7%
	40 - 49	10	22.2%
	50+	5	11.1%
Education	Primary	16	35.6%
	Secondary	13	28.9%
	College	11	24.4%
	University	5	11.1%
Employment	Employed	13	28.9%
	Non Employed	32	71.1%
Children in HH	Children	24	53.3%
	No Children	21	46.7%
Children's Age	Below 5 yrs.	17	37.8%
	6 - 10 yrs.	4	8.9%
	Above 10 – 18 yrs.	3	6.7%
Household Size	1 - 3 hhs	32	71.1%
	4 - 6 hhs	12	26.7%
	7 + hhs	1	2.2%

There were 45 (39%) of household heads who reported occurrence of diarrhea in the households. Of these 45 households, 24 had children within the household. The age distribution of the children within the households who reported occurrence of diarrhea was as follows; 17 (37.8%) of children were 5 years and below, 4 (8.9%) were between 6 years and 10 years of age while 3 (6.7%) of the children were more than 10 years to 18 years.

4.3 Main sources of water used by households of Bandani

Water vendors were the main sources of water for a majority (28.6%) followed by wells (26.1%) and taps (22.6%). A majority (51.3%) treated water before use, mostly by boiling (46.2%) and adding chlorine-based solutions (44.9%). Decantation was less commonly used (14.1%).

Table 4.4: Main sources of water of households of Bandani and treatment methods

		N (115)	**%**
Main water source	Water vendor	33	28.6
	Tap water	26	22.6
	Well water	30	26.1
	Other sources	26	22.6
Do you treat your water	Yes	59	51.3
	No	56	48.7
Treatment method			
Boiling water	Yes	36	46.2
	No	42	53.8
Adding chlorine based solutions	Yes	35	44.9
	No	43	55.1
Decantation	Yes	11	14.1
	No	67	85.9
Other methods	Yes	8	10.3
	No	70	89.7

Only 30 households (26.1%) considered wells the main source of water. However, all respondents (100%) had used water from a well at the time of the survey. For a majority, the wells were located at less than 20 meters from a pit latrine (52.2%), were not protected from animal interference (53.9%), and had plumbing leaks (50.4%). The signs of equipment used in water treatment were nonexistent for a majority (53.1%), while 40.8% had safe water storage

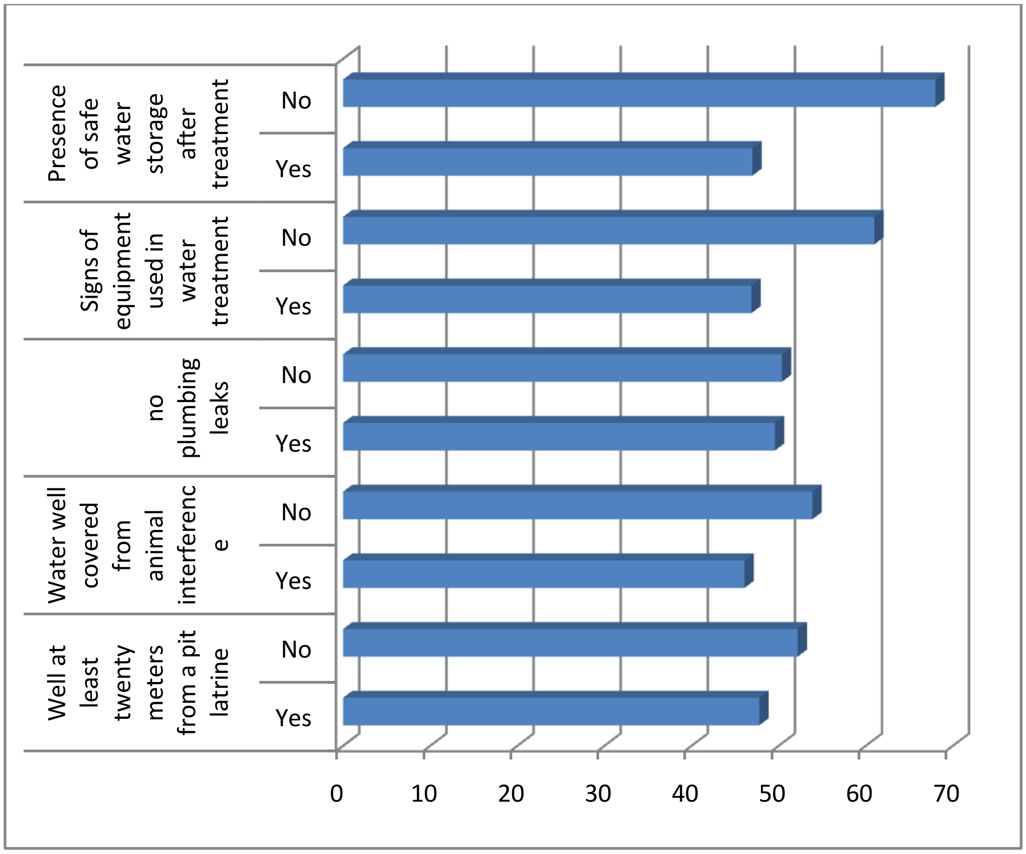

Figure 4.3: Percentages the well characteristics for households in Bandani settlement, Kisumu County

4.4 Proportion of households with bacterially contaminated water

Of the 115 households visited, 49 had contaminated water translating to a prevalence of 42.6% (34.5-50.7%).

Table 4.5: Proportion of households with bacterially contaminated water

		N (115)	% (95% CI)
Water sample	Contaminated	49	42.6 (34.5-50.7)
	Not contaminated	66	57.4 (49.3-65.5)

Socio demographic characteristics of household heads did not influence the presence of contaminated water in homes statistically significantly ($p>0.05$). This is illustrated in Table 4.6 below.

Table 4.6: Proportion of households with bacterially contaminated water by demographic characteristics

		Contamination			
		Yes (49)	**No (66)**	**χ2**	**p value**
Gender	Male	24 (36.9)	41 (63.1)	2.684	0.101
	Female	25 (50.0)	25 (50.0)		
Education	Primary	6 (54.5)	5 (45.5)	5.250	0.154
	Secondary	18 (51.4)	18 (48.6)		
	College	18 (42.9)	24 (57.1)		
	University	7 (26.0)	20 (74.0)		
Employment	Employed	28 (37.8)	46 (62.2)	1.930	0.165
	Unemployed	20 (48.8)	21 (51.2)		
Children in household	Yes	43(41.3)	61 (58.7)	1.355	0.244
	No	6 (54.5)	5 (45.5)		

4.5 Relationship between episodes of watery diarrhea, water source, and bacterial contamination

Diarrhea episodes were higher when the main water source was vendors (48.9%) compared to a tap (38.2%), well (37.5%) and other sources (32.4%) but not statistically significantly (P>0.05). However, the prevalence of diarrhea episodes was higher in homes with bacterially contaminated water (50.8%) compared to clean water (31.8%) statistically significantly ($\chi2$ =5.601, P= 0.018).

Table 4.7: Relationship between episodes of watery diarrhea, sources of water and bacterial contamination

		Diarrhea episodes			
		Yes (46)	**No (69)**	**χ2**	**p value**
Water source	Water vendor	16 (48.5)	17 (51.5)	2.460	0.483
	Tap water	10 (38.4)	16 (61.6)		
	Well water	11 (36.7)	19 (63.3)		
	Other sources	9 (34.6)	15(65.4)		
Contamination	Yes	25 (51.0)	24 (49.0)	5.601	0.018
	No	21 (31.8)	45 (68.2)		

CHAPTER FIVE

DISCUSSION

5.1 Introduction

In designing and conducting this study, the intention was to evaluate the relationship between episodes of watery diarrhea and water sources and the presence of contaminated water in households in an informal settlement in Kisumu County, Kenya. Households were recruited, questionnaires were administered, water samples collected and microbiological analyses done and the history and severity of watery diarrhea evaluated using a pretested study questionnaire.

5.2 Prevalence of diarrhea amongst the households of Bandani

From the data, diarrhea seemed to be a health problem in Bandani, with approximately 40% of households found to be affected. Muriithi, (2014) and Winter et al., (2019 had similar findings in Kibera and Korogocho slums in Nairobi respectively, with rates of between 17% and 30% reported. Even though a majority or diarrhea cases in this study did not result in a hospitalization, interventions that can lower watery diarrhea incidence are warranted as the rate is among the highest in Kenya. Provision of clean drinking water to households should be prioritized, especially to households with children and unemployed household head, as they had the highest risk of watery diarrhea episodes in the population studied. Proper sanitation facilities and sensitization on proper storage and handling of water can also help.

5.3 Main sources of water used by households of Bandani

From the data, households of the Bandani informal settlement relied mainly on water vendors to satisfy their daily needs for water, even though wells and piped water were also commonly used. Available evidence suggests that this is a common trend in other comparable informal settlements in Kenya. In a 2020 public health study of a Nairobi slum, Sarkar, (2020) identified water vendors to be the commonest sources of water. Overdependence on water vendors was also reported in Malawi (Adams, 2018). However, the finding is not similar to reports of Kimani-Murage & Ngindu in a 2007 study in Langas, an informal settlement in Eldoret, where 91% of households of the informal settlement depended on wells as the main source of water. The different population characteristics might explain this difference. The difference in time of conducting the study may also have contributed to this difference. The water vendors are becoming more popular in urban settings. Bandani, unlike Langas, which is a mainly rural settlement, is an urban informal settlement with space limitations. From this finding, sensitization of water vendors in informal settlements such as Bandani should be prioritized to prevent distribution of low quality water. Regulation of water venders to better service delivery in terms of price and quality should also be prioritized, as they are the main source of water.

The findings showed that the well characteristics of households of Bandani mirrored those of households of other informal settlements in Kenya. Even though only 26.1% of households had well in compounds, a majority of those with well had questionable well characteristics, which was a recipe for infectious disease transmission. Most wells were situated less than 20 meters from pit latrine due to small land sizes, were susceptible to animal interference, and had plumbing leaks due to poor maintenance – predisposing water to contamination. Water storage practices were also mostly poor in a majority of households – a common finding. In a study by Kimani-Murage & Ngindu in Uasin Gishu in 2007, well characteristics were poor in Langas with the distance to latrines found to be short 40% of the time. In similar studies in Manyatta, Nyalenda, and Bandani, similar findings were reported in 2015 and 2018 (Okotto et al., 2015; Simiyu et al., 2019). Even though wells are a sustainable source of water for the poor, their health risks are diverse. Regular checks should be done to ensure compliance to health and sanitation guidelines as most in Bandani were in a deplorable state. Well water should be used in other activities other than drinking; interventions such as lining programs, well protection, and chlorine dispensers should be instituted, and proper storage of water post-collection should be encouraged.

5.4 Proportion of households with bacterially contaminated water

An evaluation of water sourced and stored water indicated a high level of bacterial contamination in 42.6% of households. Even though the demographic characteristics of households were not associated with the prevalence of contaminated water in homes, well characteristics such as proximity to pit latrine, animal exposure, and leaks, and poor water storage practices were contributors. The data was comparable to the findings of Kimani-Murage & Ngindu in 2007 that most water sources in Langas, Eldoret, were contaminated with bacteria and fecal matter. The data was also similar to findings of Myint et al., (2015) in Myamar and Osiemo et al., (2019) in Marigat, Baringo County where water contamination was prevalent in homes, especially during the wet period. Therefore, this finding shows that there is need for behavior change in terms of sanitation of water wells and water storage in homes. Contamination through run-off could be prevented by proper maintenance of wells, as this was lacking in the studied population, while efforts to provide clean tap water to informal settlements such as Bandani should be prioritized.

5.5 Relationship between episodes of watery diarrhea, water source, and bacterial contamination

The data demonstrated a positive, statistically significant association between the presence of contaminated water in homes and episodes of watery diarrhea. Diarrhea episodes were 19.2% higher in homes with contaminated water, highlighting the need for immediate action. This is a common finding in Kenya (Njuguna et al., 2016; Soboksa et al., 2020). To lower diarrhea episodes and improve quality of life, proper handling, or drinking water should be encouraged. Boiling and use of chlorine agents should also be encouraged and proper sanitization maintain, especially in household whose primary source of water is a well.

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

This study had shown that the prevalence of diarrhea in household of Bandani informal settlement is quite high (40%). The prevalence of diarrhea was significantly higher in households where households head was unemployed and had children.

The main sources of water used by households of Bandani informal settlement were water vendors, wells and taps.

42.6% of the households had bacterially contaminated water after laboratory testing.

The prevalence of diarrhea was higher in households with bacterially contaminated water than in households that had no contamination after testing in the laboratory.

6.2 Recommendations

To reduce the prevalence of diarrhea in households, residents of informal settlement should be encouraged to always treat drinking water to improve its safety and to use pots with taps in order prevent water contamination when fetching the water.

The rising number of water vendors are considered as a game changer in the water supply chain. They should be regulated, trained and involved actively in the process of water quality improvement towards the objective of reducing bacterial water contamination and ultimately improving the health outcomes.

Health policy makers should encourage effective education programs with other relevant stakeholders such as Ministry of Public Health and Sanitation to incorporate public health education and economic empowerment component and provide trainings to households in informal settlements on the importance of hygiene and sanitation through house to house visits. This will tackle the relationship between contaminated water in the household and the relationship to prevalence of diarrhea.

6.3 Suggestions for future research

There needs to be further research on the effect of water vendors in the distribution and supply of water to the households.

There should be research on the sources of water that is delivered by the water vendors, more data should be collected to inform the final consumer of the delivered water.

There should be further research on the effects of other factors apart from water contamination including family size, presence of children, education and other demographic factors on the occurrence of diarrhea and other water borne diseases in informal settlements.

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APPENDICES

APENDIX 1: CONSENT TO PARTICIPATE IN THE STUDY

You are requested to participate in a research study conducted by Shem Rakewa**,** who is pursuing a degree of Master of Public Health from School of Public Health and Community Development, Maseno University.

The purpose of this study is to contribute to the knowledge of prevalence of diarrheal diseases and bacteriological contamination of water used by households of Bandani informal settlement in Kisumu West sub county, Kisumu County. You are therefore requested to participate and your sincerity in answering the questions is highly encouraged.

Your participation in this study is voluntary, and your non-participation will not in any way affect you. Also, confidentiality is highly maintained in this study and at no time will you be required to identify yourself by name. The research does not pose any physical risk that would warrant the termination of the study. The study may cause some discomfort to you through possible reminders of past events that you would rather forget. However, counseling support services will be availed to you through referral should you require the same. Participating in this study will not yield direct monetary benefits. However, the findings of the study will be shared with the Department of Health so that policy-makers will be better informed about safe water management and maintenance practices for reduced diarrheal diseases.in informal settlements

Please feel free to contact Maseno University Ethics Review Committee (MUERC) should you want any information or launching any complain

Lastly, if you agree to participate in the study, you would be required to sign this consent form.

Sign………………………………………

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APPENDIX 2: SWAHILI CONSENT FORM (FOMU YA IDHINI)

Unaombwa kushiriki katika utafiti unaofanywa na Shem Rakewa ambaye anataka shahada ya Uzamili wa Afya ya Umma kutoka Shule ya Afya ya Umma na Maendeleo ya Jamii, Chuo Kikuu cha Maseno.

Kusudi la utafiti huu ni kuchangia ujuzi wa utayarishaji wa ugonjwa ya kuhara na uwepo wa bakteria katika maji yetu tunayo tumia kwa nyumba zetu Katika kitongoji duni ya Bandari. Kwa hiyo, unaomba kushiriki kikamilifu na kuarifiwa zaidi kuwa huu utafiti ni muhimu sana na uaminifu wako katika kujibu maswali unahamasishwa sana.

Ushiriki wako katika utafiti huu ni kwa hiari, na kutoshiriki kwako hautakuathiri kwa njia yoyote katika kituo hiki. Pia, usiri unaendelezwa sana katika utafiti huu na hakuna wakati utahitajika kujitambulisha kwa jina. Utafiti hauhusishi hatari yoyote ya kimwili au ya kisaikolojia ambayo ingeweza kuthibitisha kusitishwa kwa utafiti . Zaidi ya hayo, kushiriki katika utafiti huu hautatoa faida yoyote ya moja kwa moja; hata hivyo, matokeo ya utafiti yatashirikiwa na Idara ya Afya ili wasimamizi wa sera wawe na ufahamu bora zaidi kuhusu uhudumu wa maji safi na upungufu wa ugonjwa ya hara katika masingira yetu.

Tafadhali kuwa huru kuwasiliana na Maseno University Ethics Review Committee (MUERC) unapotaka kujua mengi kuhusu utafiti hii au unapokuwa na shida lolote ile.

Hatimaye, ikiwa umekubali kushiriki katika utafiti, unahitajika kutia saini kwenye fomu hii ya idhini.

Saini...

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APPENDIX 3: HOUSEHOLD QUESTIONNARE

Household ID__________

Well ID: ______Pipe ID: _______Other sources (state):_______________________________

SECTION A

1. How many are you in this household? __________

   (Mko wangapi katika nyumba yenu?)
2. Do you have any children in this household?(if NO, Skip to question 5)_______

   (Je, kuna watoto katika nyumba hili?)
3. How many children are in this household?_________

   (Je, watoto ni wangapi katika nyumba hili?)
4. How old are the children in this household?

   (umri ya watoto hao ni upi?)

   0-5 years

   6-10 years

   11-20 years

   21-30 years
5. What is your highest level of education?

   (Umefikia Kiwango kipi cha elimu?)

   No formal education (hujasoma/ hujaenda shuleni kabisa)

   Primary School (shule ya msingi)

   High School/ Some High School (shule ya sekondari)

   University/ Some University (chuo kikuu)

   Technical School (chuo cha ufundi)

   Graduate School (shahada ya pili/ master's degree)
6. Are you currently employed?

   (Je, umeajiriwa kwa sasa?)

   Working

   Not currently working
7. How much do you make in a month in Kshs? ______________________

(unapata pesa ngapi kila mwezi?)

8. On average, How much do you spend on water per day? ____________KSH_

(unatumia pesa ngapi katika kununua maji kila siku?)

SECTION B

9. What is you main source of water for household use? (Je, unatoa wapi maji yako ya matumizi ya nyumbani?)

Individual water sellers (unanunua maji)

Dug well (ulichimba kisima) Well ID #: _______

Piped water source (maji ya mfereji) Pipe ID #: __________

More than one: _______________________________

9a. why did you decide touse this water source? Was it easier to access? Cheaper?

____

9b. **(If the primary water source is not a well)** Have you ever used water from a dug well before? (umewahi kutumia maji ya kisima?)

Yes

No

9c. **(If they use a well)** Were you always using this well? _______________

If no, what did you use before? ______________________________________

(ulitumia hiki kisima mbeleni? Ikiwa hapana, ulitumia nini?)

9d. **(If other source)** Why did you switch? ____

(kwa nini uliacha kutumia maji kutoka mahali pengine?)

9e. How do you treat the drinking water before using it?

Do your boil it? Yes No

Add chlorine to it? Yes No

Other methods(specify) ____

(unatibu maji yako baada ya kuchota? Unachemsha? Unaongeza dawa ya chlorine?)

10. **(If they use a well or have used a well)** Where is the well located?

(kisima kiko wapi?)_______________________________________

11. Estimate how long it takes you to get to the well. ______________________________________

(unachukua muda gani kufika katika kisima?)

12. Is it your own well or does it belong to someone else? Is it a private or public well? ____

(Ni chako au ni cha mtu mwingine?)

13. **(If it is their well)** Why did you decide to dig your well? ____

(kwa nini uliamua kuchimba kisima chako [yako]?)

14. Have you ever had this well tested for bacteria or other forms of contamination? ____

(umewahi kuangaliliwa ikiwa kisima chako kiko katika hali nzuri?)

15. What do you usually use the water for? ____________________________

Laundry? Yes No

Drinking? Yes No

(unatumia maji haya kufanya nini? Kufua? Kunywa? Kuoga? Kuosha vyombo? Kupika?)

16. How do you retrieve the water from the well? _______________________________________

Do you lower a bucket? Yes No

Do you use a pump? Yes No

(unachotaje maji kutoka kisima? Unatumia ndoo?)

17. Do you have or use a pit latrine? Yes No

If yes, Can you show it to me? Pit Latrine ID #: _____________

<u>SECTION C</u>

1. In the past two weeks, have you or anyone in your household been ill? ____

(mtu yeyote au wewe amekuwa mgonjwa **wiki mbili** uliyopita katika nyumbani yako?)

1a. Which person in the family was this? ____

How old are they? ________________

Gender: Male Female

1b. Do you know what the illness was? Could you describe the symptoms? (ikiwa ndiyo, unajua

ulikuwa ugonjwa gani? Unaweza kuelezea dalili?)

____

1c. did you take this person to the hospital? __________________

1d. **(If yes),** Do you have the hospital records? __________________________________

1e. how long were you or the household member sick? ________________________________

(Uligonjeka au aligonjeka kwa muda gani?)

1f. Had the sick person ever drank from a well? ____________________________________

(Mgonjwa aliwahi kunywa maji ya kisima?)

If they say the sick person was not taken to a hospital or if they say that no one has been ill, then

ask this question:

2. Have you or anyone in your household had three or more watery stools within 24 hours in the past two weeks?

____

(Umehara [umeendesha] au yeyote nyumbani katika masaa ishirini na nne kwa wiki mbili zilizopita?)

2a. What do you think caused the illness? (Unafikiri ugonjwa ulisababishwa na nini?)

____

Thank you very much! Asante sana!!!!!

APPENDIX 4: OBSERVATIONAL CHECKLIST

SR-01

Tap located near home. The tap itself is nearly buried under mud, there is a hose attachment that runs from it to allow for water collection. The tap is located right next to a sewage ditch but I did not observe the pipe running through the water in the sewage ditch.

SR-02

Well has no cover and is full to the brim from recent rains. The well opening is not raised far from the ground, water could easily run from surrounding area right into the well. Located near a sewage ditch.

SR-03

Well is raised from the ground but located very close to a pit latrine. Well has a cover that can be locked. Families use a bucket to collect the water.

SR-04

Located close to pit latrine. No sewage ditches nearby. The opening to the tap is nearly buried, they attach a long hose to use this pipe. Private pipe with lock on it.

SR-05

Located near house. Using a long hose to collect water. Not near sewage ditch. Cover on tap to be able to lock it.

SR-06

Well has no cover. Right by latrine and sewage ditch.

SR-07

Has a cover. Not located near sewage ditch.

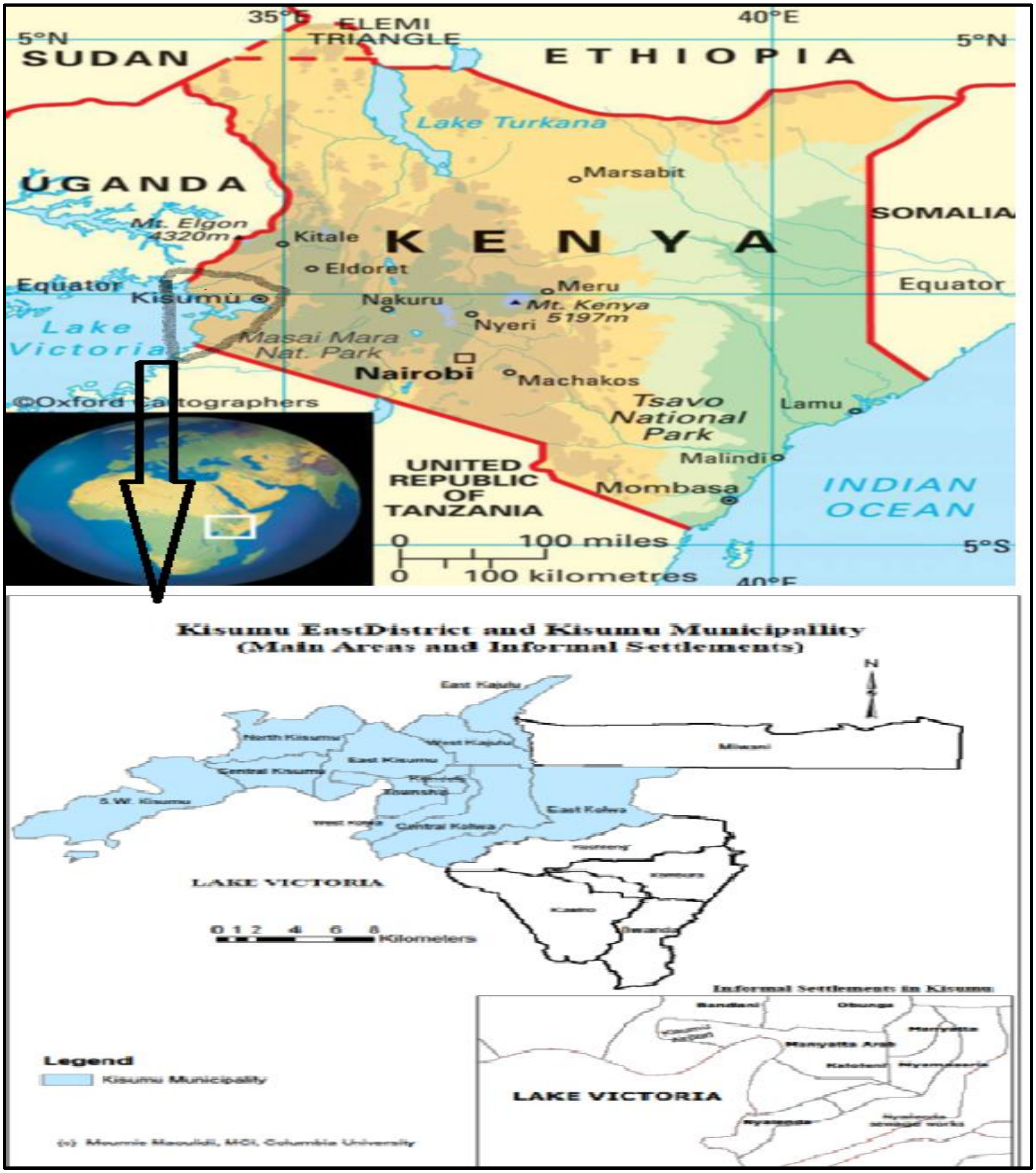
SR-08

Well has a cover and opening is slightly raised. Not near drainage.

SR-09

The well's opening is raised and it has a cover. Located near the road and very close to pit latrine.

APPENDIX 5: MAP HIGHLIGHTING THE STUDY AREA



APPENDIX 6: PROPOSAL APPROVAL LETTER

MASENO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Office of the Dean

Our Ref: MPH/PH/0064/2014

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
mail: sgs@maseno.ac.ke

Date: 11th September, 2019

TO WHOM IT MAY CONCERN

RE: PROPOSAL APPROVAL FOR SHEM RAKEWA — MPH/PH/0064/2014

The above named is registered in the Masters of Public Health Degree Programme in the School of Public Health and Community Development, Maseno University. This is to confirm that his research proposal titled "Prevalence of Bacterial Contamination of Water Used by Residents of Bandani Informal Settlement in Kisumu West Sub County, Kisumu County Kenya." has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

Prof. J.O. Agure
DEAN, SCHOOL OF GRADUATE STUDIE

APPENDIX 7: MUERC APPROVAL LETTER

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

FROM: Secretary - MUERC

DATE: 27th February, 2020

TO: Shem Rakewa
PG/MPH/PH/00064/2014
Department of Public Health
School of Public Health and Community Development
Maseno University
P. O. Box, Private Bag, Maseno, Kenya

REF: MSU/DRPI/MUERC/00779/19

RE: Prevalence of Bacterial Contamination of Water used by Residents of Bandani Informal Settlement in Kisumu West Sub County, Kisumu County, Kenya. Proposal Reference Number MSU/DRPI/MUERC/00779/19

This is to inform you that the Maseno University Ethics Review Committee (MUERC) determined that the ethics issues raised at the initial review were adequately addressed in the revised proposal. Consequently, the study is granted approval for implementation effective this 27th day of February, 2020 for a period of one (1) year. This is subject to getting approvals from NACOSTI and other relevant authorities.

Please note that authorization to conduct this study will automatically expire on 26th February, 2021. If you plan to continue with the study beyond this date, please submit an application for continuation approval to the MUERC Secretariat by 15th January, 2021.

Approval for continuation of the study will be subject to successful submission of an annual progress report that is to reach the MUERC Secretariat by 15th January, 2021.

Please note that any unanticipated problems resulting from the conduct of this study must be reported to MUERC. You are required to submit any proposed changes to this study to MUERC for review and approval prior to initiation. Please advice MUERC when the study is completed or discontinued.

Thank you.

MASENO UNIVERSITY SECRETARY 27 FEB 2020 ETHICS REVIEW COMMITTEE

Dr. Bonuke Anyona,
Secretary,
Maseno University Ethics Review Committee.

Cc: Chairman,
Maseno University Ethics Review Committee.

MASENO UNIVERSITY IS ISO 9001:2008 CERTIFIED

APPENDIX 8: NACOSTI LICENSE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 913033

Date of Issue: 31/March/2020

RESEARCH LICENSE

This is to Certify that Dr.. SHEM Oliech RAKEWA of Maseno University, has been licensed to conduct research in Kisumu on the topic: PREVALENCE OF BACTERIAL CONTAMINATION OF WATER USED IN BANDANI INFORMAL SETTLEMENTS IN KISUMU EAST SUB-COUNTY, KISUMU COUNTY, KENYA. for the period ending : 31/March/2021.

License No: **NACOSTI/P/20/4597**

913033

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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