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Quality of Water in Relation to Diarrheal Disease Incidence in Obunga

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Abstract

Kenyan cities are experiencing a serious dilemma in dealing with the large influx of people from rural parts of the country to the cities. Most people come to the city in pursuit of better opportunities and jobs. Rapid urban growth with little planning and preparation by the national and county governments has led to the development of informal settlements. These informal settlements are characterized by poor environmental conditions that predispose their residents for poor health conditions. Because of their illegal status, most residents of informal settlements in Kenya do not receive government services such as water, drainage, sewerage, and rubbish collection. This study will focus specifically on the lack of proper water supply in these informal settlements. Informal settlements usually use well water, public taps, or water vendors in order to get the water they need. The water options are not always adequate or safe. This study seeks to understand the use of well water in the informal settlement Obunga located in Kisumu County, Kenya. The study looks at the proximity of wells to pit latrines and how this affects the bacteriological quality of the water. The results found that there was no correlation between well contamination and distance from pit latrine and no correlation between diarrheal disease and the distance of a water source from a pit latrine. There was, however, a correlation between drinking dirty water and experiencing diarrhea. This finding suggests that contaminated water does indeed cause diarrhea. The study also found that there was not adequate access to safe drinking water in Obunga since 100% of the sampled wells tested positive for fecal coliforms. Taps were found to be the safest water source with only 10% contamination, but there are simply not enough taps in Obunga to serve the growing population of residents.

I. Introduction

Informal Settlements

Rapid urban growth in a climate of economic constraints and poor resource management has resulted in the majority of residents in Africa's large cities to live in overcrowded slums and temporary settlements. The increase in these temporary housing settlements has been driven by urbanization that pulls poor rural families into the city in search of jobs and greater opportunities (Lamba, 1994). Poverty has increasingly become a crucial urban problem in Kenya. As more rural Kenyans move to cities, the informal settlements have grown and the urban infrastructure has struggled and failed to keep up. The slums have overwhelmed the environmental health resources in urban areas. Because of their illegal status, most residents of informal settlements in Kenya do not receive government services such as water, drainage, sewerage, and rubbish collection. The lack of government services causes informal settlements to have environmental conditions that predispose their inhabitants to poor health outcomes. In most of the informal settlements, garbage is left to collect along the road side or is burned, sewage runs right by people's doorsteps and streets flood during the rainy season.

The right to health is provided under the Kenyan constitution but in practice this right is often violated. In Kenya, health was not a Constitutional right until August 2010. Before that time, paying out-of-pocket for health services was how most people were able to access any type of health care at all (Chuma, 2012). The Kenyan health sector is very clearly inequitable and benefits are often not distributed on the basis of need but instead on the basis of ability to pay. This means that impoverished informal settlement residents often have a difficult time going to a formal healthcare facility and consequently exhibit higher mortality rates than residents of other areas (APHRC, 2002). This is detrimental because the environmental health in these settlements

is some of the worst in the country leading to high disease burden among the population. Diseases such as typhoid, cholera, dysentery, malaria, TB, and HIV are very common. People living in informal settlements therefore find themselves living in an environment that contributes to disease and with few resources to access healthcare for treatment. While this situation is a clear violation of their human right to health, little to nothing has been done to rectify the situation.

Water and Human Waste in Informal Settlements

This study will focus specifically on the lack of proper water supply in these informal settlements. Having access to an adequate supply of safe drinking water is universally recognized as a basic human need and right. Yet globally, at least 1.8 billion people use a drinking-water source that is contaminated with feces (WHO, 2016). By 1996, the number of people without access to safe water in urban areas was rising sharply in developing countries as a result of rapid urbanization (WHO, 1996). Because the United Nations projects a rapid population growth in urban areas between 2000 and 2030, (United Nations Population Division, 2000) access to safe drinking water in urban areas is likely to worsen unless there is a drastic policy change to cater to the needs of the urban poor.

In addition to the problems associated with poor access to water are issues with ways of dealing with human excreta. Public defecation and urination is very common in Kenya where there is little access to public restrooms and often many people in temporary settlements have no bathroom of their own. Although some homes do have self-contained flush toilets, the use of pit latrines is the most popular and least expensive form of restroom used in the informal settlements. Contamination of water is common because of poor infrastructure for people to relieve themselves. In countries like Kenya, even when toilet facilities are available there is

usually a charge for using them. This causes people with little to no money to choose open defecation or urination over paying to use the available restrooms. Open defecation has been implicated in the spread of many infectious diseases including cholera, typhoid, and hepatitis. It is estimated that one-third of deaths in developing countries are caused by the consumption of contaminated water (WHO, 1997). The World Health Organization estimates that 502,000 people die annually from diarrheal diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management (Murray, 1996). Contaminated water can transmit diseases such as diarrhea, cholera, dysentery, typhoid and polio. In Kenya, diarrheal diseases are among the major illnesses affecting children in informal settlements. According to the report by the African Population Health Research Center in 2002, prevalence of diarrhea was around 32% among children below 5 years of age in the slums (APHRC, 2002).

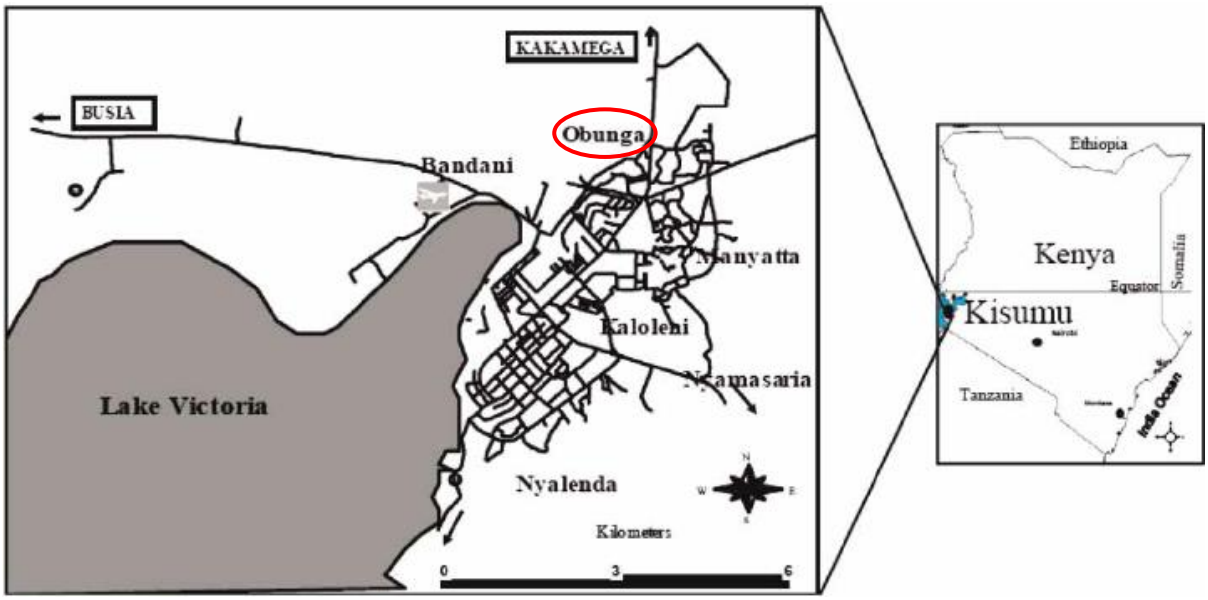
Many slums depend on wells to supply cheap water for communities in urban slums. Regulations have been put in place to prevent these wells from being built too close to pit latrines, but often there is little enforcement of these rules. The general rule of thumb is that pit latrines should not be built within 15 meters of a well, but urban slums are often so densely populated that it is difficult for residents to keep track of these requirements and as a result, circumstances arise where a pit latrine and well are in some cases less than a few meters apart. The opportunity for contamination increases the closer human excrements are released to fresh water. This poses a serious public health and human rights issue. Water can become an expensive commodity for poor slum dwellers in Kenya. Even if a family owns their own well, they may still be forced to purchase water and end up using their own, less safe, well water only

when there is lack of funds to purchase cleaner tap water. This leads to the utilization of cheaper but less safe options for drinking water.

Ia. Study Location

The study site is located in Kisumu City in western Kenya. Kisumu City is situated on the eastern extremities of Lake Victoria. The city is at an elevation of approximately 3860 ft above sea level. Kisumu has two rainy seasons. The city has a long rainy season from March through May and a short rainy season from August through October. Less precipitation falls during Kisumu's dry season around January. The total area covered by the city is approximately 417 km^2 (UN Habitat, 2006). The city has a core residential area surrounded by higher density unplanned settlements. One of these unplanned informal settlements is Obunga located north of the Kisumu city center (Map 2). This settlement forms the focus of the current study. Obunga was formed when the colonial government forced the inhabitants out of Kisumu. Its population grew when it developed as a fish market, as the economy of Kisumu expanded. Around one-fifth of the households say that they have evidence of ownership – for instance, sale agreements of land transactions, government allotment documents or inheritance documents (Karanja, 2010). Very few households have water connections or toilets on their plots and many use pit latrines or the bush for defecation. In Obunga around 94% of residents use pit toilets, only .6% use flush toilets (Maoulidi, 2012). The area Obunga is situated in faces serious problems with flooding during the long rains and many areas are waterlogged. Electricity is available but very few households are connected. There is no primary or secondary school nor health care facility in the settlement. Obunga has a high density of housing structures mostly made up of mud and iron sheets although there are a number of more permanent concrete structures as well. The population of Obunga in 2009 was 14,747 people. There were 4,099 households living in an area

of 1.3 km^2. That is a population density of around 11,282 people per km^2 (Kenya National Bureau of Statistics, 2010). Common economic activities here include selling vegetables, charcoal, second hand clothes, fish and running of small food kiosks in order to make ends meet. In general, the majority lives in a vicious circle of poverty. Water remains a large issue in this area. Most of the homes in Obunga do not have running water or waste removal services. The average monthly water expenditure for Obunga residents is Ksh. 797 or $9.30 USD (Maoulidi, 2012).



Map 2: Location of the informal settlement Obunga in relation to the Kisumu city center.

II. Statement of the Problem

In many urban slums in Africa where ground water is a source of domestic water, use of pit latrines is often not recommended because of over population and the likelihood of contamination of ground water. Where they coexist, although, the commonly used guideline is that the well should be located higher than and at least 15 m from pit latrine. Available evidence shows that increased lateral separation between the source of pollution and groundwater supply

reduces the risk of fecal pollution (ARGOSS, 2001). Coexistence of latrines and use of underground water has in the past been mainly confined to the rural areas where there is adequate land to allow for adequate distance between pit latrines and shallow wells. However, with the rapid expansion of slum settlements in Kenya, on-site sanitation and underground water are used in some urban areas because they are affordable options in the absence of government-supplied services. The congestion in the urban slums does not allow for adequate distance between the wells and the pit latrines. This mean that micro-organisms can migrate from fecal contents into the underground water sources leading to contamination of the water and consequently water-borne diseases like cholera. It is in this context and that of high levels of diarrheal diseases in the urban slums of Kenya that this study seeks to assess the sanitary practices and the fecal contamination of shallow well water in the urban slum of Obunga. The study seeks to determine if proximity of wells and pit latrines in Obunga is indeed leading to the contamination of these water sources and whether or not this is translating into diarrheal disease.

III. Objectives

The broad objective of this study was to determine the quality of well water in the Obunga slum of Kisumu, Kenya.

Specific objectives:

1. Establish the sources of water in Obunga.
2. Identify all shallow wells within the study area.
3. Determine bacteriological quality of shallow wells, deep wells and pipes in study area.
4. Determine the presence of water related diseases in the area.
5. Establish correlations between well contamination and disease presence in Obunga.

IV. Literature Review

Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum

This 2007 study done by researchers Elizabeth Kimani-Murage and Augustine Ngindu looked into overcrowding in the Langas slum of Kenya. It studied the degree of water contamination in wells caused by overcrowding and poor sanitary practices. The study found that 91% of residents in the Langas slum used wells as the main source of domestic water, the rest used tap water. Elizabeth and Augustine also found that although most people used pit latrines for excreta disposal, a substantial percentage (30%) of children excreted in the open field. The estimated distance between the pit latrines and the wells was generally short with about 40% of the pit latrines being less than 15 m from the wells. The main domestic water sources were found to be highly contaminated with fecal matter. Total coliforms were found in 100% of water samples from shallow wells, while 97% of these samples from shallow wells were positive for thermotolerant coliforms. None of the samples from taps was positive for either total or thermotolerant coliforms. Because the presence of thermotolerant coliforms in water indicates fecal contamination, facilitated by the proximity between the wells and pit latrines, the study's findings suggests that the pit latrines were a major source of contamination of the wells with fecal matter. Water run-off from rain was also noted as being a potential cause for contamination. This study was important because it proved the importance of distance between the depository for human waste and drinking water. It also showed that rules regulating these building parameters are not often enforced. The study, however, did not identify important qualitative information on reasons for using well water in the area or whether the contamination was actually leading to disease. Families may have been treating the water (boiling or adding chlorine) but we do not know for sure from this study.

Cholera Outbreaks in W. Kenya Blamed on Contaminated Water

Similar to this study, there was a blog post in 2008 that was entitled "Cholera Outbreaks in W. Kenya Blamed on Contaminated Water". According to the blog, health officials said the main reason for cholera outbreaks was because of seepage from the latrines. Senior Deputy Director of Medical Services in Kenya's health ministry, Shahnaaz Sharif, was reported as saying that, "In Kisumu, many wells are built near the latrine; eventually the sewage seeps into the wells." One of the leading causes of diseases among Kenyans, such as cholera, is due to a lack of access to safe water (Gunter, 2011). This post showed the general public's view on the issue and also determined that this was indeed a serious issue in Kisumu specifically.

Groundwater, self-supply and poor urban dwellers: A review with case studies of Bangalore and Lusaka

This 2010 book written by Gordon McGranahan, Martin Mulenga and Jenny T. Grönwall, seeks to shed light on why and to what extent people in urban poor areas use groundwater for drinking and other domestic purposes; strategies employed to access the water; the implications of the dependence on groundwater; and what this should mean in terms of policy and regulation. It contains two case studies – of the cities of Bangalore, India, and Lusaka, Zambia – in order to substantiate the limited amount of statistics and literature in the field. The study highlights the problems with policies that do not address issues with contaminated groundwater and only seek to expand piped lines to low-income, unplanned slums. The study highlighted the vital role of groundwater for the urban poor and the need for more literature surrounding it. This book highlights why well water is so important for these communities,

specifically because of its low cost. The authors shed light on why the urban poor in these developing countries use groundwater, how they access it, what they use it for, what the issues are surrounding groundwater use and how policy makers should go about addressing them. The book does a good job of bridging the gap between the problem and what to do about it. It provides more information on the communities and why this form of water use is important not only to policy makers but also to the people in the communities themselves.

In-house contamination of potable water in urban slum of Kolkata, India: a possible transmission route of diarrhea

This study was conducted by Anup Palit, et.al in 2012. It investigated and determined the potential of different water sources, both for drinking and domestic purposes, in diarrheal disease transmission. Out of 517 water samples, collected from different sources, stored water (washing) showed higher prevalence of fecal coliforms (58%) ($p < 0.0001$) in comparison with stored (drinking) samples (28%) and tap water (8%) respectively. Among different sources, stored water (washing) samples had the highest levels of contamination. The study highlighted the importance of good storage practices for water. It showed that water contamination could occur after the water had been collected from the water source. This is an important variable to consider when studying well water quality and disease because contamination could be occurring after the water has been retrieved form the well.

A longitudinal Study of Long- Term Change in Contamination Hazards and Shallow Well Quality in Two Neighborhoods of Kisumu, Kenya

Research conducted by Kisumu- based environmentalist, Joseph Okotto, in partnership with local and UK based universities, showed that 46 wells whose water was tested were recharged by water that passes through pit latrines. It was found that the wells were dug very close to the ground, unprotected and when it rains and given the near non-existent garbage collection in the city, all the dirt from human waste to oil are washed into the wells. The study observed that pit latrines have been constructed as close as three meters to the wells. The study showed that in Kisumu the water table is very close to the surface, meaning that digging as little as four meters can get one to the water— an advantage that Mr. Okotto says spells a lot of danger for the residents. The researchers searched for thermotolerant coliforms, whose presence would signify contamination. The study was beneficial in developing a protocol for long-term monitoring of both contamination risks and well water quality. It also showed that well water and pit latrine usage has been increasing in Kisumu since 1999. However, in examining long-term change in shallow well water quality, the study doesn't look at the potential short-term impact of rainfall events. Short-term studies can better measure the noticeable immediate effects of rainfall on the quality of groundwater. The study also did not look into disease incidence in the communities it studied to see whether the contamination was actually translating to disease. This study also does not give much information about the households that use these wells for instance why they decided to build their well where they did, how they treat water before using it, or reasons for why they choose to use groundwater.

V. Methodology

This research combined primary and secondary information gathered from literature reviews, interviews, field notes/ observations, and raw data collection. Phase 1 of the project incorporated breaking the study site up into five units. The five units were Kamakowa, Kasarani, Central Unit 1, Central Unit 2, and Sega Sega. Next, the location of all pit latrines, wells and taps were recorded using the GPS Coordinator Application and mapped using ArcGIS. Distance between the water sources and the pit latrines was calculated using ArcView. The distances were categorized into two classes: within 15 meters and greater than 15 meters of a pit latrine. Then 10 wells and 10 taps were randomly selected. Of these 10 wells and 10 taps, 5 were within each distance category. Next, Community Health Volunteers (CHV) received training and were organized to conduct interviews (see Appendix) with around 100 families that used these 20 water sources. The goal was set to conduct interviews with heads of 5 households per water source (Images 1 & 2). The interviews sought to gain demographic information on the residents of Obunga, how much they spend on water per day, issues with accessing water, and any incidences of diarrheal diseases. The interviews provided information that was then used to make a water and disease profile on each household. They were conducted in Swahili and Lou by CHVs in order to ensure that the participants felt at ease and better understood the questions being asked. The CHVs were selected by a local council and were Obunga residents that people in the community knew and trusted. One CHV was chosen from each Unit in Obunga.

The next phase in the project included the collection of 100mL water samples from the 20 randomly selected water sources. The samples were collected aseptically with sterile sampling containers and tested at the Kisumu Water and Sewage Company (KIWASCO) labs for fecal and total coliforms. The samples were transported to the lab in a cooler with ice around 3

hours after being collected. Next, the GPS locations for all of the households that had been interviewed by the CHVs were collected. All of the data was mapped, complied, and analyzed using ArcGIS. The data was stored in a secure Excel file that had no identifiable information about participants in the study. Each household, well and tap were given a specific individual ID to identified them by. 2x2 Chi Squared tests were used in data analysis after all of the data had been collected.

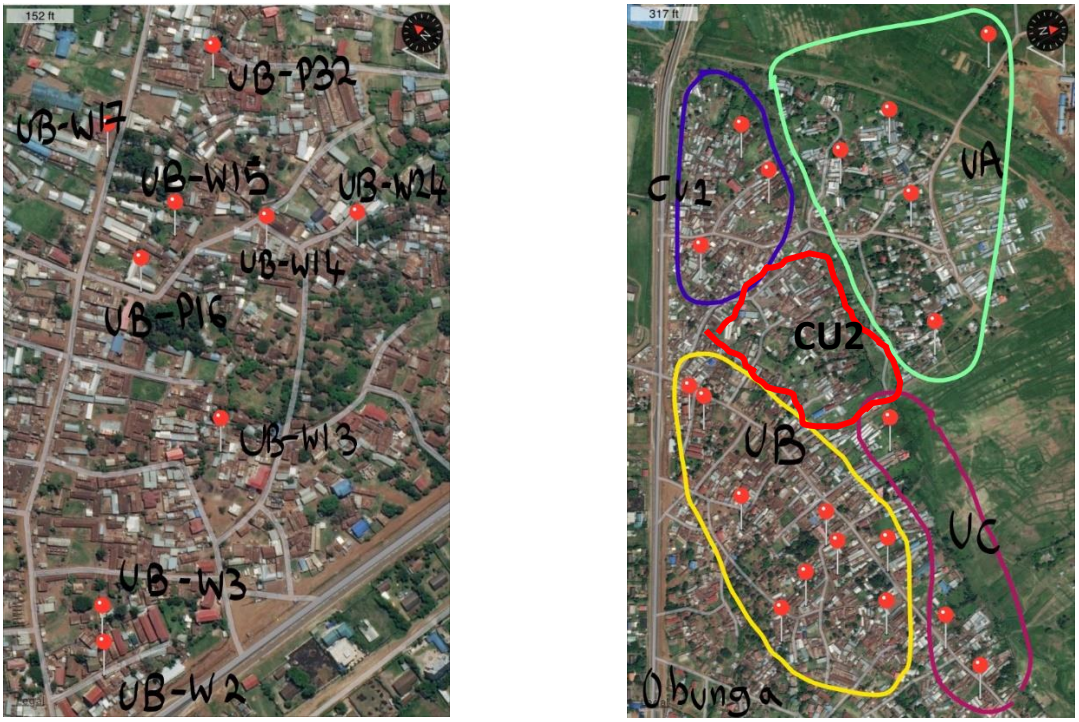
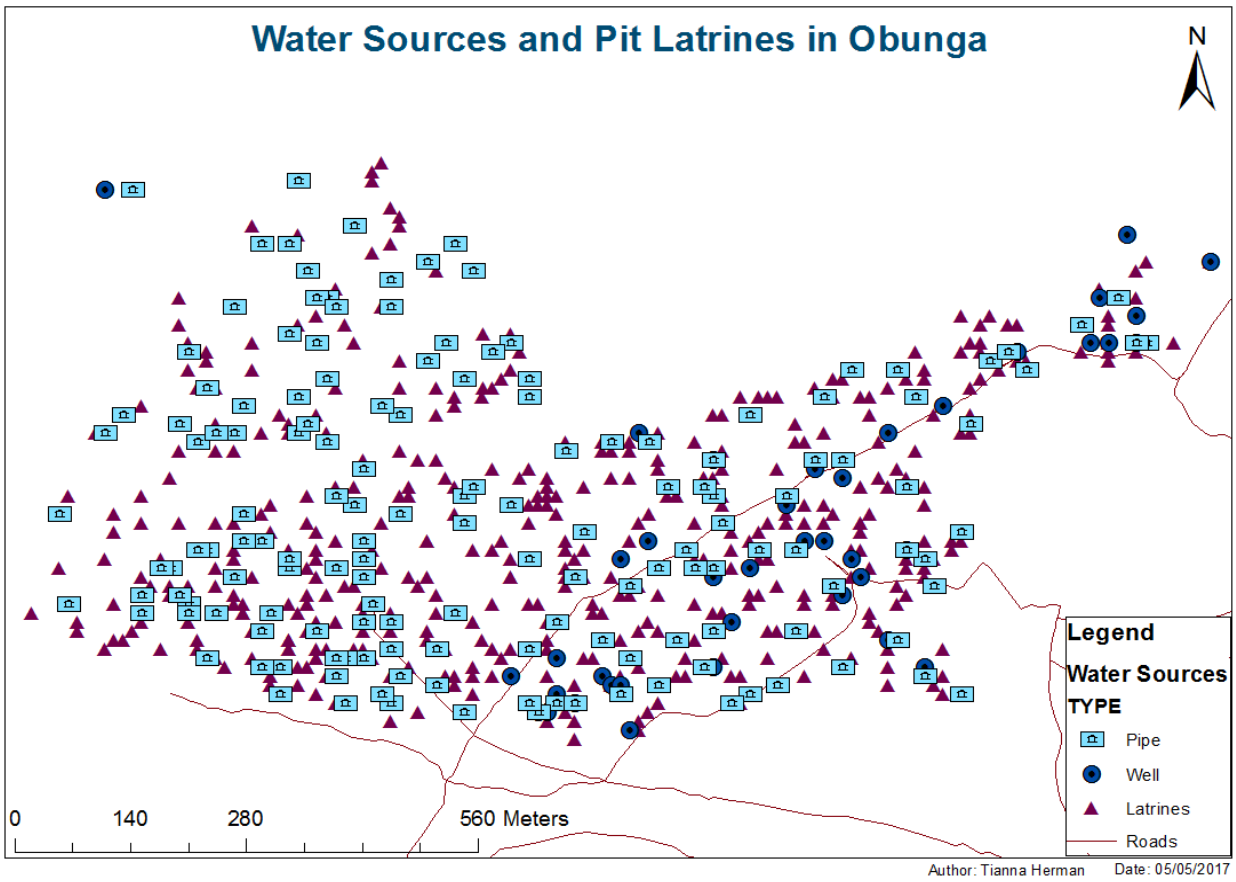


Image 1 & 2. Maps used by CHVs to identify the tested taps and wells when conducting interviews.

VI. Results & Analysis

Sources of Water in Obunga

The main sources of water in Obunga are taps, wells and water from vendors. A total of 195 water sources were recorded. That is around 76 people per water source. 79.5% of the water sources in the study site were taps and only 20.5% were wells. The opening to the wells were sometimes raised from the ground with concrete slab openings that could be closed. But often the openings where at ground-level and were poorly covered (See Appendix). Those that used well water often used it only for household activities like doing laundry, cleaning, mopping, bathing, etc. Most people had to spend money to either buy drinking water from a local neighbors tap or from a water vendor. Only 25.6% of the people using well water actually drank from the well. Many households that used wells, said they did not use tap water for domestic purposes because it was too expensive. Of the households that were interviewed, the average amount of money they spent per day on water was around 30 shillings. Most of the heads of household were unemployed so their well was often a cheaper alternative because the water was free for them but they did not use it for drinking because most realized that well water was not safe for consumption.



Map 1. Sources of water and pit latrines in Obunga

Human Waste Disposal

There are 463 active pit latrines in Obunga. With a population of around 14,747 people, that is around 32 people per pit latrine. Since pit latrines usually service one family, this simply means that there are families that do not own their own pit latrine. These families either use a neighbor's pit latrine, use public restrooms where they pay a fee, or they defecate in the open. Most of the pit latrines that were observed were simple raised concrete platforms with metal sheeting to cover it. Others were a little more sophisticated with improved ventilation and more solid structure.

Distance between Pit Latrine and Well

The estimated distance between the pit latrines and the wells was generally short with about 45% of the pit latrines being within 15 m of the wells. The mean distance between wells and pit latrines was 17.6 meters. The distance between taps and latrines was also recorded for comparative reasons. Around 42.2% of taps were within 15 meters of a latrine and the mean distance between them was 17.5 meters.

Treating Drinking Water

The majority of the study population was using taps for drinking water. 78.6% of participants drank from taps, while only 25.6% drank from wells (Table 1). This is positive because it shows that residents in Obunga are knowledgeable about some of the health issues associated with drinking well water. 50.6% of participants using any water source treated their water either by boiling it over by adding chlorine and 49.4% did not treat their water. Despite the short distance estimated between the pit latrines and the wells and the poor sanitary practices like indiscriminate excreta disposal, only 41% of those who reported using wells said they boiled their drinking water. Treating well water before use is proven to greatly reduce the chances of getting a diarrheal disease but with that being said, the study found no correlation between water treatments and not getting diarrhea or even getting diarrhea (Table 2). This means that even when participants treated their well or tap water, there were still reported cases of diarrhea. There were also cases where participants did not treat their water and did not have any reported cases of diarrhea. The overall conclusion is that the reported cases of diarrhea were not related to water contamination and could have resulted from other factors such as contaminated food.

	Tap	Well	P-value
Drinking	78.6% (n=33)	25.6% (n=10)	<0.0001

Table 1. Percentage of households that drank well or tap water.

Water Type	Water Treatment	Tap	Well	P-value
Diarrhea	No	90% (n=9)	10% (n=1)	0.24
	Yes	60% (n=3)	40% (n=2)	
No Diarrhea	No	75% (n=15)	25% (n=5)	1.0
	Yes	75% (n=6)	25% (n=2)	

Table 2. Correlation between drinking water and diarrhea incidence.

Water Analysis Results

Twenty water samples were analyzed: 10 from wells and 10 from taps. There was a statistically significant difference between contamination of the tested wells as compared to the taps. The tested wells were found to be highly contaminated with fecal matter. Total coliforms were found in 100% of water samples from wells. Only 10% of the samples from taps were positive for either total or fecal coliforms. The presence of total and fecal coliforms in water indicates fecal contamination. With that being said, the study found no correlation between distance from pit latrine and well water contamination (Top section of Table 3). Since wells that were both within 15 meters of a pit latrine and greater than 15 meters from a pit latrine were found contaminated the study could not conclude that the pit latrines were the major source of contamination of the wells with fecal matter. Water run-off from the long rainy season was also noted as being a potential cause for contamination.

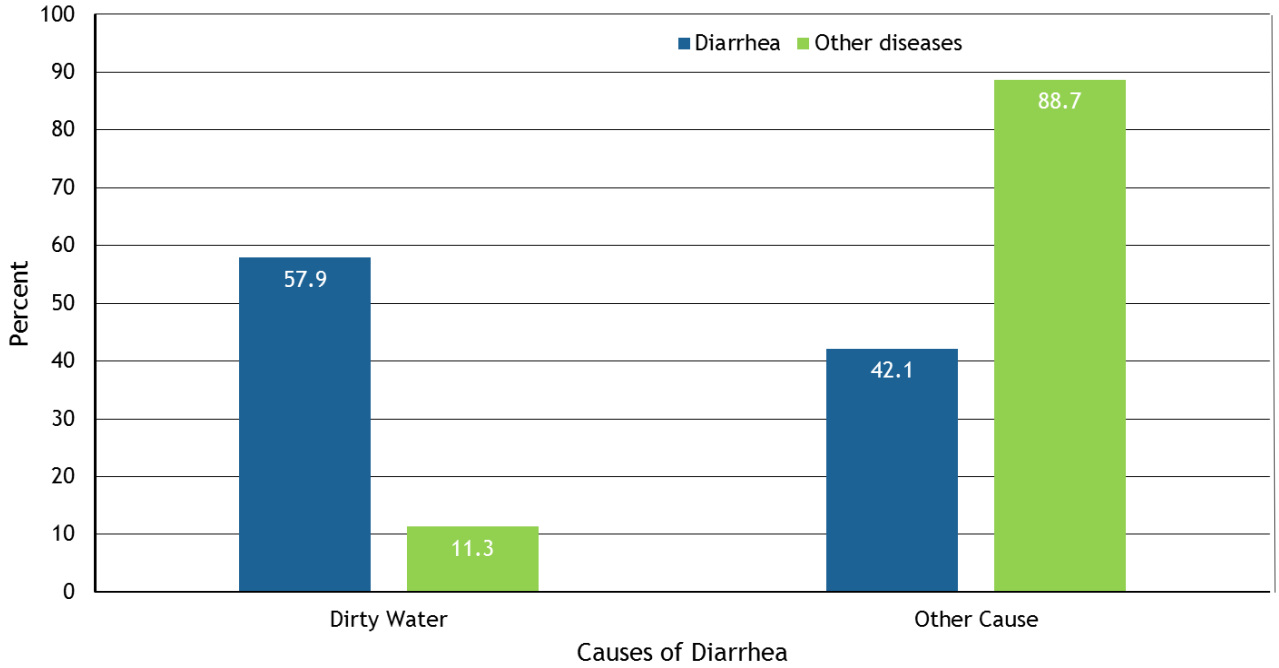
DISTANCE (to pit latrine)	Tap (n=10)	Well (n=10)	P-value
Water Sources			
Less than 15 meters	0% (n=0)	100% (n=5)	0.01
Greater than 15 meters	20% (n=1)	100% (n=5)	0.05
Overall	10% (n=1)	100% (n=10)	0.01
Diarrheal Disease			
Less than 15 meters	13.3% (n=2)	0% (n=0)	0.48
Greater than 15 meters	40.7% (n=11)	24% (n=6)	0.25
Overall	31% (n=13)	15.4% (n=6)	0.12

Table 3. Bacteriological quality of wells and taps and presence of diarrheal disease. This distance between taps and latrines was also recorded and analyzed for comparative purposes. There is no literature supporting taps being contaminated by latrines. There was a significant difference between contaminated wells as compared to taps. There was no correlation between distance from pit latrine and water contamination. There was no correlation between the diarrheal disease and the distance between a water source and pit latrine. There is no difference between disease incidence when using a well vs. a tap that is greater than 15 meters from a latrine or less than 15 meters from a latrine.

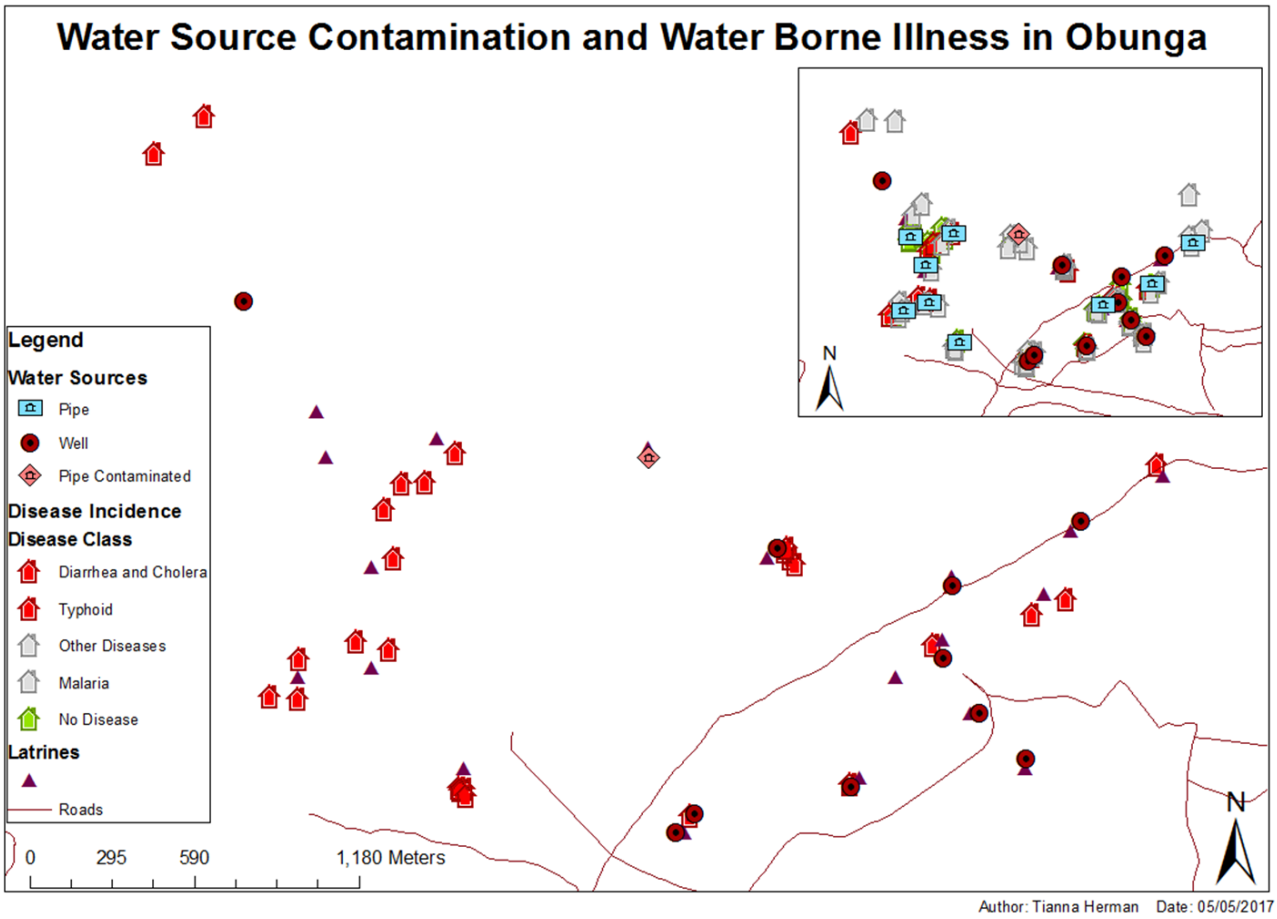
Disease Incidence Results

A total of 95 households were sampled (Map 2). There was an 85.3% reported incidence of disease. 32.1% of the reported diseases were related to diarrhea and typhoid, 44.4% were related to malaria and 23.5% were related to various other diseases. The study found no correlation between the diarrheal disease incidence and the distance between a water source and a pit latrine. Of the households that participated in the study, none reported a diarrheal disease that used a well within 15 meters of a pit latrine but 24% reported a diarrheal disease that used a well greater than 15 meters of a latrine (lower portion of Table 3). This was because most of the participants did not use well water for drinking. Of the families that did drink from a well, there was a strong

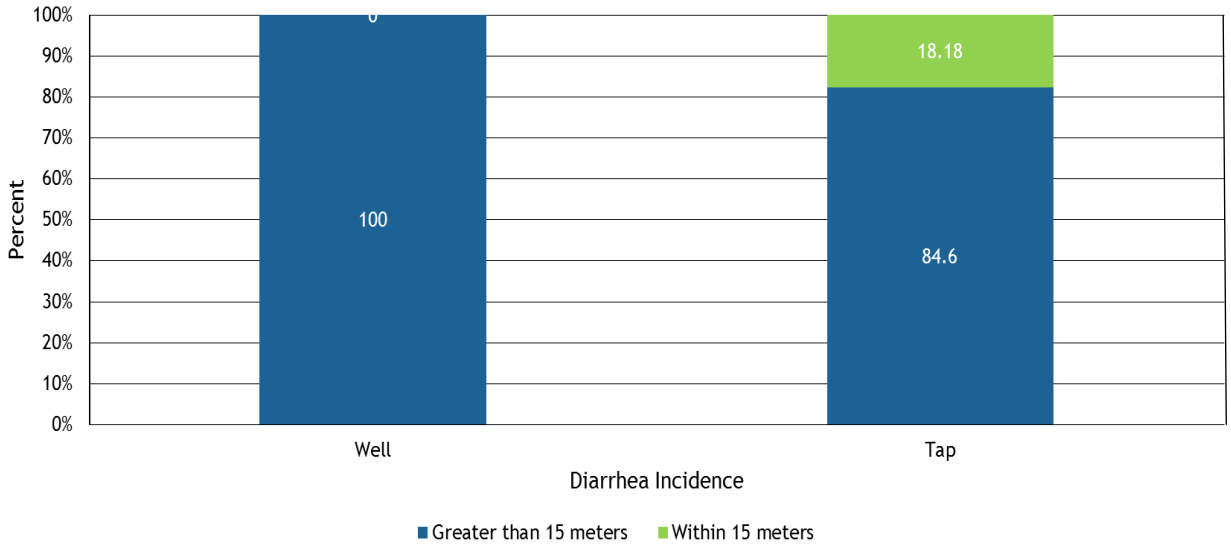
correlation (57.9%; p-value= <0.0001) between drinking the dirty water and experiencing a diarrheal disease (Graph 1). This suggests that dirty water does in fact cause diarrheal diseases. There, however, was no correlation between the well's distance from a pit latrine and resulting diarrheal diseases. Since all of the wells were contaminated, the lack of diarrheal disease among households using them could have been explained by the low percentage of families drinking from wells. Table 3 shows an interesting set of data in that the wells are all contaminated but there are less cases of diarrheal diseases reported than among families that use them, whereas of the families that use taps (of which only one was contaminated) there were more cases of diarrheal disease. These data would have been concerning but there is not a statistically significant correlation between the overall diarrheal incidence for taps compared to wells. This findings suggests that tap water is not actually a main cause for diarrhea even though there were more reported cases from families that used taps.



Graph 1. Reported Causes of Diarrhea. The graph shows that there was a correlation between use of dirty water ('well water', 'spring water', 'outside water') and diarrhea.



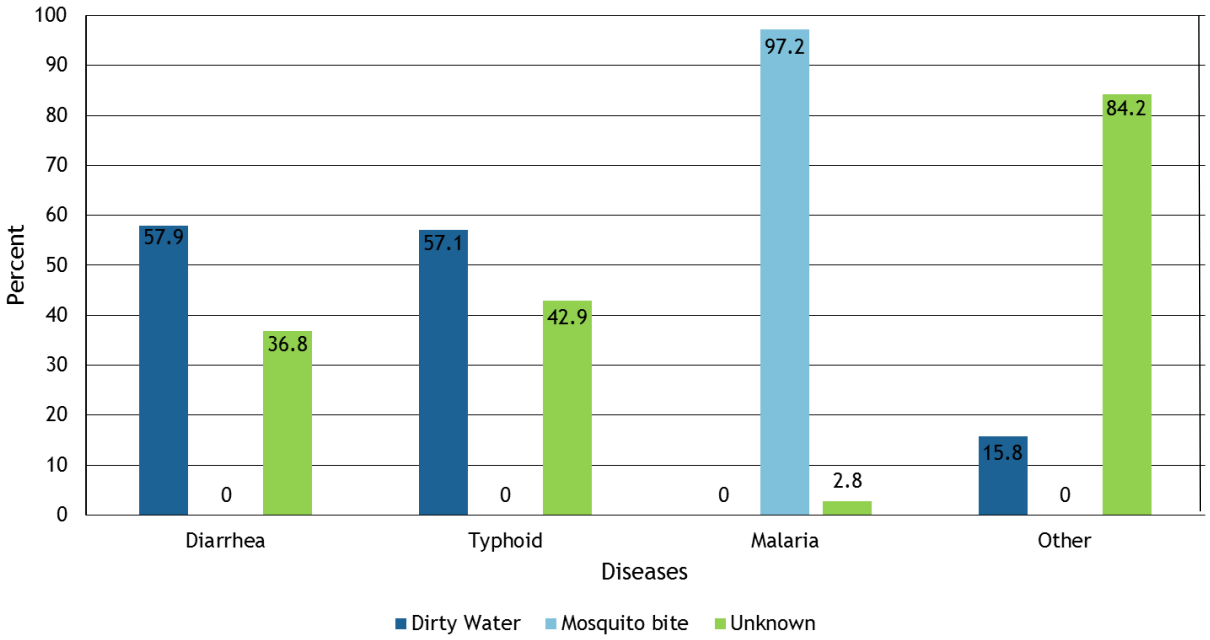
Map 2. Water Source Contamination and Water Borne illnesses in Obunga. This map shows the geographic location of the households that were interviews and what diseases they reported if any. It also shows the location of the 20 water sources that were tested and their contamination status. The map shows that there was little correlation between contamination and diarrheal disease.



Graph 2. Indicence of Diarrhea in Relation to Distance from Latrine. When we focused in on the households that experienced specifically diarrhea alone (23.5%), we saw that 100% of those diarrhea cases were among households whose primary water source was a well greater than 15 meters of a latrine and 0% from those using a well within 15 meters of a latrine. For households that used taps, 84.6% of the diarrhea cases were from those that use a tap greater than 15 meters from a latrine as their primary water source and 18.2% were among households that use a tap within 15 meters of a latrine.

Perceptions on Reasons for Illnesses

Over 50% of the study population had knowledgeable perceptions about the causes of their illness. 97.2% of participants acknowledged that they got malaria from a mosquito bite, 57.9% of participants reported that they got diarrhea or cholera from dirty or contaminated water and 57.1% reported getting typhoid from dirty water. This information is important because it shows that of the study population, a majority seem to be aware of what causes their illness and therefore would know how they could avoid getting ill. This does not mean though that they have the means to avoid getting sick. Also, many participants did not report going to the hospital. Many either went to a dispensary to get drugs, went to a local herbalist, or simply waited for the illness to pass. This finding means that often the diagnosis is not official and participants were often self-diagnosing.



Graph 3. Perceptions on causes of disease.

VII. Conclusion

After identifying all of the water sources available to residents of Obunga, this study shows that although there are wells and taps available for use, there is still a need for the city to expand access to safe drinking water in Obunga. 100% of the wells tested were positive for fecal and total coliforms. This findings shows that none of the wells are a safe option for drinking water regardless of their distance from a latrine. The need for increased access to piped water is evident. The extent of contamination of well water in Obunga was shown through the water analysis results although the causes of the contamination remain unknown. The possible causes being either proximity to a pit latrine or rain run-off recharging the wells and causing fecal contamination.

The results indicate that the conditions in Obunga do not fulfill the recommendations given for coexistence of onsite sanitation and the use of ground water since 45% of pit latrines

were within 15 meters of a well. Although the distance between the wells and pit latrines did not adhere to the WHO guidelines for drinking water, the study found no correlation between water contamination and distance from pit latrine or between diarrheal disease incidence and the water source's distance from a pit latrine. The lack of correlation between contamination and distance from latrine is reasoned to be because of the long rainy season that brought storms almost every evening to the Kisumu region. The area that Obunga is located in is faced with serious flooding issues during the long rains and many areas are waterlogged. The area is so sodden that houses often sink into the ground.

Improving the water quality at source alone may not be the ultimate solution to improving the quality of water in informal settlements because improving water quality at source may not always ensure a reduction in the transmission of water-related diseases. Studies have shown significant deterioration in water quality between the source and the point of use. The lack of correlation between diarrheal disease and the distance of the water source from a pit latrine could be caused by the low percentage of participants that actually drank from a well. The strong correlation between drinking dirty water and experiencing diarrhea suggests that dirty water does indeed cause diarrhea but the cases of diarrhea that were reported among the study population may not have been water borne. There were cases where participants using tap water experienced diarrhea. This could have been caused by food instead of water, but it could also be that water is being contaminated after being drawn from the source.

The results of this study suggest that tap water is safer, but additional sampling is needed for both taps and wells to form a sold conclusion.

VIII. Recommendations & Limitations

Because of its many limitations this study was unable to form any solid conclusions on the effect of pit latrines on well contamination or on the correlation between diarrheal disease and a well's distance form a latrine. I, therefore, recommend that this study be redone for a longer period of time. A study on the effect of latrines on well water should be done over the long rainy season, the dry season and the short rainy season to allow for a better understanding of how the changing seasons affect water contamination. I also recommend testing for the presence of *E. coli* or other specific bacteria in order to have a more accurate analysis of the water contamination. This study was only able to test for fecal and total coliforms. Also to be more accurate the study should test samples from the pit latrines as well to determine if the fecal contamination is from the latrine or simply from run-off.

Another limitation to the study was the sample size for the household questionnaire. The sample size was 95 households, which is not large enough to generalize its findings to all of Obunga's residents. I recommend a larger more robust sample be collected to look at a greater percentage of households in Obunga, allowing stronger conclusions on the relationship between diarrheal disease and water contamination in the study site. A study of this magnitude would require more funding and time for a more in-depth analysis of the topic.

IX. Appendix

Consent Form Format

SIT Study Abroad

a program of World Learning

Consent to Participate in a Research Study
KEMRI ● Obunga, Kisumu

Title of Study: Quality of Shallow Well Water in Relation to Diarrheal Disease Incidence in Obunga

Investigators:

Name:	**Tianna Herman**	**Title:**	Student Researcher	**Phone:**	+254 799 560207
Name:	**Maurice Ombok**	**Title:**	KEMRI Researcher	**Phone:**	+254 710 312176
Name:		**Title:**	Community Health Worker	**Phone:**	

Introduction

- You are being asked to be in a research study on well water contamination in Obunga.
- You were selected as a possible participant because you live in Obunga and are within 2 [two] miles of a well.
- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study

- The purpose of the study is to determine if wells in Obunga are contaminated and if the contamination is leading to diarrheal diseases among households that use that wells as their primary source of water.
- Ultimately, this research may be presented as a paper or possibly published in a journal.

Description of the Study Procedures

- If you agree to be in this study, you will be asked to do the following things:
  -Answer honestly to each question asked in the interview.
  -Be available to participate in any consecutive meetings if follow-up information is needed.

Risks/Discomforts of Being in this Study

- There are no reasonable foreseeable (or expected) risks. There may be unknown risks.

Benefits of Being in the Study

- The benefits of participation is the potential for this study to further understanding on the quality of well water in in Obunga for use by local officials to work on correcting public policy.

Confidentiality

- The records of this study will be kept strictly confidential. Research records will be kept in a locked file, and all electronic information will be coded and secured using a password protected file. Audio recordings of the interviews will be used only by the researchers and will be permanently erased after they have been transcribed. We will not include any information in any report we may publish that would make it possible to identify you.

Right to Refuse or Withdraw

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study *at any time*. You have the right not to answer any single question, as well as to withdraw completely from the interview at any point during the process; additionally, you have the right to request that the interviewer not use any of your interview material.

Researcher's Contact Information

- You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, Tianna Herman at hermantianna@gmail.com or by telephone at +254 799 560207 or contact my advisor at MOmbok@kemricdc.org . If you like, a summary of the results of the study will be sent to you.
- If you have any problems or concerns that occur as a result of your participation, you will be referred to Dr. Steve Wandiga at KEMRI for filling a complaint.

Consent

- Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep.

"I have read the above and I understand its contents and I agree to participate in the study. I acknowledge that I am 18 years of age or older."

Subject's Name (print): _____

Subject's Signature: _____ Date: _____

Investigator's Signature: _____ Date: _____

Consent to Quote from Interview

I may wish to quote from the interview either in the presentations or articles resulting from this

work. A pseudonym (fake name) will be used in order to protect your identity.

Initial one of the following to indicate your choice:
_____ (initial) I agree to allow the researcher to use quotes from the interview.
_____ (initial) I do not agree to allow the researcher to use quotes from the interview.

RIGHTS OF RESEARCH PARTICIPANT – IRB CONTACT INFORMATION
In an endeavor to uphold the ethical standards of all SIT proposals, this study has been reviewed and approved by an SIT Study Abroad Local Review Board or SIT Institutional Review Board. If you have questions, concerns, or complaints about your rights as a research participant or the research in general and are unable to contact the researcher please contact the Institutional Review Board at:

School for International Training
Institutional Review Board
1 Kipling Road, PO Box 676
Brattleboro, VT 05302-0676 USA
irb@sit.edu
802-258-3132

Interview Format

Interview

Introduction Section (ninamasowali machche)

Do you understand the objectives of this study? (unaelewa ni kwa nini ninafanya haya masomo?)

Do you have any questions or concerns about the study? (una maswali yoyote kuhusu haya masomo?)

Do you agree to be a part of the study? (unakubali kuwa mmoja wa masomo haya?)

Household ID: _____

Interviewer's Name: Tianna Herman Date: _____

Interviewee's name: _____

Well ID: _____

Pipe ID: _____

Water Section

1. How large is your family? _____
   (kuna watu wangapi katika family yako?)
2. How many children do you have in your household? _____
   (una watoto wangapi katika nyumbani yako?)
   How old are they?
   ☐ 0-5 years
   ☐ 6-10 years
   ☐ 11-20 years
   ☐ 21-30 years
   ☐ 31-40 years
   ☐ 41 + years
3. What is your highest level of education?
   (umesoma mpaka wapi?)
   ☐ 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)
4. What is your employment status as of today?
   (unafanya kazi gani?)
   ☐ Working
   ☐ Not currently working
5. How much would you say you earn per month? _____
   (unapata pesa ngapi kwa mwezi (yani mshahara wako ni pesa ngapi)?)
   (Kwa mwezi moja unapata pesa ngapi?)
6. How much, on average, do you spend on water per day? _____KSH_
   (kwa siku unatumia pesa ngapi kwa maji?)
7. What is your primary source of water? (Unapata maji yako wapi?)
   ☐ Individual water sellers (unanunua maji)
   ☐ Dug well (ulichimba kisima) Well ID #: _____
   ☐ Piped water source (maji ya mfereji) Pipe ID #: _____
   ☐ Store bought bottled water (maji ya chupa) Store Location: _____
   ☐ More than one: _____

   7a. Why did you decide to use this water source? Was it easier to access? Cheaper?
   _____

7b. **(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

7c. **(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?)

7d. **(If other source)** Why did you switch? _____

(kwa nini uliacha kutumia maji kutoka mahali pengine?)

7e. How do you treat the drinking water before using it? _____

Do your boil it? ☐ Yes ☐ No

Add chlorine to it? ☐ Yes ☐ No

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

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

(kisima kiko wapi?)

_____

9. Estimate how long it takes you to get to the well. _____
(unachukua muda gani kufika katika kisima?)
10. 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?)
11. **(If it is their well)** Why did you decide to dig your well?
_____
(kwa nini uliamua kuchimba kisima chako [yako]?)
12. Have you ever had this well tested for bacteria or other forms of contamination?
_____

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

13. 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?)

14. 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?)

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

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

Health Section- Move on to this section only if the participant has stated that they currently use or have used well water.

1. In the past 6 months, have you or anyone in your household been ill?

   _____

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

   1a. Do you remember when this occurred? _____

   1b. Which person in the family was this? _____

   How old are they? _____

   Gender: ☐ Male ☐ Female

   1c. Do you know what the illness was? Could you describe the symptoms? (ikiwa ndiyo, unajua ulikuwa ugonjwa gani? Unaweza kuelezea dalili?)

   _____

   1d. Did you take this person to the hospital? _____

   1e. **(If yes),** Do you have the hospital records? _____

   1f. How long were you or the household member sick? _____

   (uligonjeka au aligonjeka kwa muda gani?)

   1g. 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 the last 24 hours?

   _____

   (umehara [umeendesha] au yeyote nyumbani katika masaa ishirini na nne yaliyopita?)

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

   _____

Asante sana!!!!!

Well and Tap Observations

UC-P22

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.

UC-W6

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.

UC-W3

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.

UB-P16

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.

UB-P32

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

UB-W17

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

UB-W14

Has a cover. Not located near sewage ditch.

UB-W3

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

UB-W2

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

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