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Bacteriological Quality of Drinking Water in Administrative Wards around Kisii Town, Kisii County, Kenya

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Abstract

Provision of quality drinking water is an important part of improving public health and is the rationale behind protecting drinking water sources and promoting healthy practices at and around sources. The study used the presumptive occurrence of faecal contamination in water samples to assess the bacteriological quality of drinking water in Kisii town and administrative wards bordering it. The objectives were to geospatially map drinking water sources, assess the bacteriological quality of drinking water, compare the risk of water from different sources and establish the contribution of hygiene practices toward water contamination around the water sources within Administrative Wards around Kisii Town. Trained community health volunteers were used to collect water samples from 64 springs, 19 open wells, 11 rainwater tanks, and 8 tap water sources. Tests were conducted using the Portable Microbiology Laboratory. The indicator bacterium Escherichia coli were detected in 76% of the water samples. Tap and rainwater were safer to drink while water from unprotected springs was highly contaminated. The highest risk cases were from central ward. This was attributed to the high level of sewage contamination and indiscriminate dumping of waste. Hygiene conditions and practices that seemed to potentially contribute to increased total coliform and Escherichia coli counts included non-protection of water sources from livestock faeces, laundry practices, and water sources being downstream of pit latrines in some cases. The findings suggested source water protection and good hygiene practices could improve the quality of drinking water where disinfection is not available. The findings also suggest important lines of inquiry and provide support and input for environmental and public health programmes, particularly those related to water and sanitation.

Keywords: Total Coliform, *E. coli*, Hygienic Practices, Households, Water Source Protection

1. Introduction

Water is the most abundant chemical in the human body and plays a central role in the regulation of nutrient transport, toxic waste removal, thermal regulation and digestion. However, if water is fecally polluted it can spreads infections to consumers. Coliform bacteria are used as microbiologic indicators for water quality and freedom from contamination with faecal matter is the important parameter of water quality because human faecal matter is generally considered a great risk to human health as it is more likely to contain human enteric pathogens .Current WHO bacteriological guidelines for drinking water recommend zero fecal coliforms for 100 ml of water. (Scott et al., 2003). Unsafe water, improper sanitation and hygiene contributes to death of about 2 million people every year most of them are children less than 5 years of age .Unsanitary water is responsible for 80 per cent of all illness and the world's number one killer. An estimated 1.3 billion people living in per capita low-income countries do not have access to safe drinking water (Ashbolt, 2004).

Rapid population growth, urbanization and the desire for better living has placed great strain on the quality of drinking water, especially in urban centres. This affects the quality of drinking water since many people don't have access to water for basic personal hygiene. (Pruss-Ustun and Corvalan, 2006). The rationale for promoting safe drinking water in developing countries is the persistently high levels of water related morbidity and mortality. Globally it is estimated that at least 4 – 5 million clinical cases annually, 80% of them in Sub-Saharan Africa are water borne related. In Kenya 26 children die daily from water borne diseases: However, previous research has indicated that, up to 70% reduction can be achieved through well-planned public health interventions. In Kisii water-borne diseases accounts for 46% of the top 10 clinical cases annually (WHO, 2004).

About 748 million people lack access to improved sources of drinking water, of which, about 173 million get water from untreated surface water. So one of the big problems now is to overcome the gap between access to adequate drinking water supply and access to quality drinking water supply (WHO, 2007).Although drinking water coverage has increased worldwide, access to reliable water quality is still a challenge. Poor water quality increases the risk to transportation and spread of diseases related to water. The assessment of the health risk from naturally occurring microbes in drinking water continues to be of a high interest to microbiologists, public health practitioners and water supply regulators (Geldreich, 2009). The most common and wide spread health risk associated with drinking water is its microbial contamination, the consequences of which are so serious that its control must always be of paramount importance. Microbiological quality should therefore be regarded as a priority, although it may be impossible to attain the targets in the short or medium term. Bacterial indicators are measured instead of pathogenic organisms, because the indicators are safe and can be measured with faster and less expensive methods than the pathogens of concern. In Kisii County, the number of households depending on piped water is alarmingly low and thus majority of them depend on water from other alternative sources like, springs wells and rainwater. These water sources are often more vulnerable to the immediate influence of many contamination sources which include leaking sewerages, defecation in the bushes, and pit latrines. (Parveen, et.al, 2008).

2. Objectives of the Study

The Specific Objectives of the Study were to:

1. To geospatially map drinking water sources within Administrative Wards around Kisii Town
2. To assess the bacteriological quality of drinking water from different sources within Administrative Wards around Kisii Town
3. To compare the Risk of Water from different Sources within Administrative Wards around Kisii Town
4. To establish the contribution of hygiene practices toward water contamination

around the water sources within Administrative Wards around Kisii Town

3. Literature Review

Access to safe drinking water is a fundamental human right and a crucial component of public health. However, in many parts of the world, the quality of drinking water remains a major concern. Contamination of drinking water with pathogenic bacteria is a significant public health issue that can lead to waterborne diseases such as typhoid, cholera, and dysentery. Therefore, assessing the bacteriological quality of drinking water is an essential step in ensuring public health and preventing waterborne diseases. In Kisii, Kenya, the bacteriological quality of drinking water has been a significant concern due to limited access to clean water sources and poor sanitation practices.

Several studies have evaluated the bacteriological quality of drinking water in Kisii, Kenya. A study by Mbogo, et al. (2010) evaluated the bacteriological quality of drinking water in Kisii town, Kenya. The study found that 44% of the drinking water samples collected from various sources, including tap water, boreholes, and open wells, were contaminated with coliform bacteria. The study also reported that the highest levels of bacterial contamination were found in water from open wells and boreholes. The findings suggest that the quality of drinking water in Kisii remained compromised, which could increase the risk of waterborne diseases.

Another study by Nyangena et al. (2010) assessed the bacteriological quality of drinking water in Nyamataro and Kiogoro markets in Kisii. The study found that the majority of the drinking water samples were contaminated with total coliform and fecal coliform bacteria, with contamination levels ranging from 43% to 100%. The study also reported that the contamination of drinking water was influenced by the source of water, storage practices, and the type of container used to store water. These findings suggest that the bacteriological quality of drinking water in Kisii remained a significant public health concern. In another study, Muga et al. (2006) assessed the bacteriological quality of drinking water in a rural community in Kisii, Kenya. The study found that 64% of the drinking water samples collected from unprotected sources were contaminated with faecal coliform bacteria. The study also reported that the prevalence of waterborne diseases was high among the study participants, indicating the potential health risks associated with poor water quality.

In a study by Chepkirui et al. (2006), the bacteriological quality of drinking water in Kisii was assessed. The study reported that the majority of the water samples collected from various sources, including springs, shallow wells, and boreholes, were contaminated with coliform bacteria. The study also found that the level of contamination varied depending on the source of water, with water from springs being the most contaminated. A study by Njiru et al. (2003) evaluated the bacteriological quality of drinking water in Kisii town, Kenya. The study found that 36% of the drinking water samples were contaminated with total coliform bacteria, and 16% of the samples were contaminated with fecal coliform bacteria. The study also reported that the highest levels of bacterial contamination were found in water from unprotected springs and shallow wells. These findings suggest that the quality of drinking water in Kisii town was compromised, which could increase the risk of waterborne diseases.

A study by Bartram et al. (2003) highlighted the importance of improving the quality of drinking water in Kenya. The study emphasized the need for effective water treatment and disinfection systems to reduce the risk of waterborne diseases. The study also recommended regular monitoring of water quality to ensure that the water supplied to the public is safe for consumption.

In conclusion, the bacteriological quality of drinking water is an important public health concern, and the quality of drinking water varies significantly depending on the source. Monitoring the bacteriological quality of drinking water is critical in ensuring public health and preventing outbreaks of waterborne diseases. The studies reviewed in this literature review demonstrate the need for continued monitoring of the bacteriological quality of drinking water and the implementation of measures to improve the quality of drinking water in various parts of the world. These findings can inform policymakers and stakeholders in implementing measures to ensure the provision of safe drinking water to the residents of Kisii.

4. Methodology

4.1 Study Area

Water samples were collected in Kisii town and administrative wards bordering the town. Kisii town is situated approximately 300 km South West of Nairobi on the highway to Mwanza, Tanzania. It has a highland equatorial climate, with an average rainfall of 2000 mm/ yr. The terrain of the study area is mostly hills and most settlements and drinking water sources are located at the foothills. Approximately 80% of the residents in the study area live in unsewered premises and are not connected to piped water. Much of the water used for domestic purposes is drawn from springs, rivers, streams, boreholes and roof catchments.

4.2 Study Design

The study adopted a cross-sectional analytical survey and utilized elements of qualitative and quantitative research methodologies. The study was conducted from July to September 2010.

4.3 Sample Collection

A water-sampling network was identified using Community Health Volunteers by mapping critical sampling points within eight (8) administrative wards. Attention was given to the most widely used water sources and sampling done precisely where water is taken for drinking purposes. The strategy was to capture all key water sources used by the community and mapping the water sources by taking geo-coordinates and photos. Water samples were collected in sterile whirl-paks fitted with screw caps, labelled, and transported for analysis within six hours of collection. Quality control was ensured by following the pre analysis, analysis and post analysis standard protocol (APHA, 2005)

4.4 Bacteriological Analysis

Bacteriological analysis was carried out for indicator organisms i.e. faecal coliform (E.coli) using the Portable Microbiology Laboratory (PML) ;A simple and effective water testing kit used at the community level to test water sources for the potential risk of disease. The PML consists of 25 Colilert and Petrifilm tests that fit inside a gallon-size zip lock plastic bag, along with Whirl-Paks to collect water samples, sterile plastic pipettes, and a battery-operated long-wave UV light for the Colilert test. Just add water and incubate.

In the Colilert test 10 ml of the water sample was added to the Colilert tube using a sterile pipette, which was then mixed by inverting the tube several times to dissolve the nutrients. The sample was then incubated at body temperature, [35ºC] to promote good bacterial growth. Tubes were placed in a small sack, or sock, and held close to the body and slept on at night since no incubator was available. The incubated tubes were examined after 24 hrs. If the tube turned yellow, UV light was shined on it to observe the presence of E. coli. In the petrifilm test, 1ml water sample was dispensed and spread onto the centre of a labelled E. coli Count Petrifilm. The plates were then left undisturbed for one minute for gel to solidify. The plates were incubated with clear side up at body temperature for up to 24 hours. This was done by stacking up to 10 Petrifilms together and placed between two pieces of firm cardboard, securing them with rubber bands, and incubating the stack close to the body during the day, sleeping on them at night.

4.5 Interpretation of Results

Colilert Test

There are three possible results: If the tube is clear, no coliforms are present, If the tube is yellow, but there is no fluorescence under long-wave UV light, coliform bacteria other than E.coli are present and if the tube is yellow and fluoresces blue when a long-wave UV light shines on it, E. coli was present in the water sample, and the water poses a substantial health risk. (UNHABITAT, 2010)

Petrifilm Test

The results can give the following: E. coli colonies will appear blue with gas bubbles. One or more E. coli colonies signifies heavily contaminated water, which should be treated before drinking, Non E. coli coliform colonies will be red with a gas bubble, Non-coliform Gram negative bacteria form red colonies without a gas bubble. Very high concentrations of E. coli will cause the growth area to turn a bluish colour with individual colonies too tiny to distinguish. Very high concentrations of non E. coli coliforms will cause the growth area a dark reddish colour with individual colonies too tiny to distinguish. If this occurs further dilution of the sample is required to obtain a more accurate count. (UNHABITAT, 2010)

Risk Assessment of Water Sources

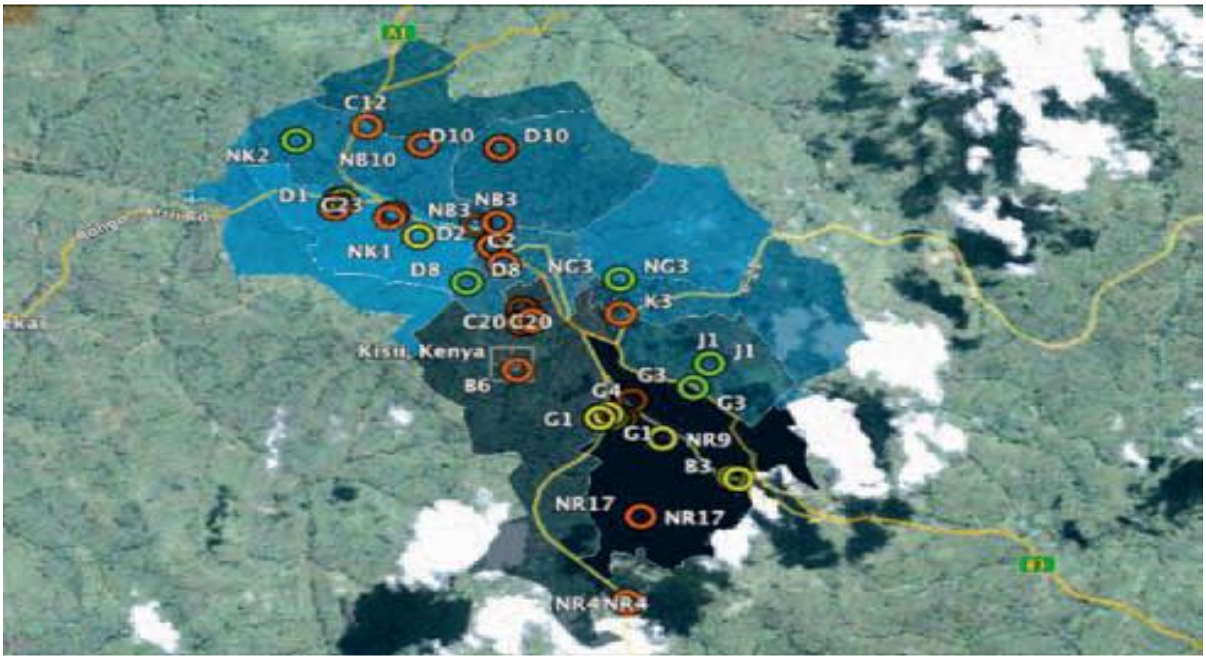
Table 1. Interpretation of Results

Coli/Sample Colilert Fluorescence Petrifilm # Blue&Gas	**Risk level**
< 1/10 ml – 0	Low
1-10/10 ml + 0	Moderate
1-10/ml + 1-10	High
>10ml+>10	Very High

5. Results and Discussions

5.1 Geospatial Mapping of Water Sources

Mapping of water sources were conducted using community health volunteers and summarized as shown in the figure below. Geo coordinates and photos of the sources were taken using a GPS machine and a digital camera .The Geo-coordinates data collected were then uploaded on an online mapping tool as indicated in the Google map below. The map is colour coded where (Green = Low Risk, Yellow = Moderate Risk, Orange = High Risk).



Geo-referenced water quality data collected using the tests in Kisii (July 2010) and represented on an online mapping tool (Green = Low Risk, Yellow = Moderate Risk, Orange = High Risk). Photo © 2010 Google

5.2 Bacteriological Quality of Drinking Water from different Sources

The presence of E. coli in 74% of the water samples analyzed is a cause for concern, as this bacterium is an indicator of fecal contamination and can cause serious gastrointestinal illnesses in humans. The high percentage of contaminated water samples suggests that the sources of drinking water need to be carefully monitored and treated to ensure safe consumption by the public. The study highlights the importance of routine water testing and the implementation of appropriate water treatment technologies to reduce the risk of waterborne illnesses. This finding is consistent with previous studies that have reported high levels of bacterial contamination in drinking water sources (Fenner et al., 2005; Momba et al., 2006).The results showing the number of water sample from different administrative wards containing E. coli were presented as indicated in Table 2.

Table 2: *Bacteriological Quality of Drinking Water from different Sources*

		Drinking Water Sources		
		Total	**Sources With E.coli**	**Percentage**
Administrative Wards	Bobaracho	16	13	81%
	Central	23	19	83%
	Daraja Mbili	18	18	100%
	Gekomu	8	3	38%
	Kanga	1	1	100%
	Kiamwasi	7	1	14%
	Kiong'ongi	2	1	50%
	Nyaura	27	20	74%
Total		**102**	**76**	**74%**

5.3 Risk Assessment of Water from different Sources

Samples from unprotected water sources had the highest risk with 61.76% of the total water samples (Table 3). This was attributed to the contamination from livestock faeces, washing clothes close to water sources, pit latrines located near and mostly upstream of water sources and waste dumping near water sources observed during the survey. This highlights the need for improved water source protection measures, such as the construction of wells, boreholes, and rainwater harvesting systems. Furthermore, public education and awareness campaigns can be implemented to encourage the use of protected water sources and to promote the importance of proper sanitation and hygiene practices. Such measures can help to reduce the risk of waterborne illnesses and improve public health. The highest risk cases were from Central and Nyaura wards with a high risk of 26% both, Kiamwasi and Gekomu wards recorded the lowest risk with 0.05% and 0.04% high risk respectively as depicted in Table 4. This finding is particularly concerning in areas where access to safe drinking water is limited, as people may be forced to rely on these unprotected sources for their daily needs. The number of cfu/100 ml from all the contaminated water sources exceeded the WHO guidelines of zero cfu/100 ml in drinking water. The variations in the number of colony forming units per 100 ml among the water sources were however wide depending on the nature of protection accorded to the water source.

Generally, the average E. coli density was relatively high in unprotected water sources compared to protected ones. Tap and rainwater was found to be safer to drink while water from unprotected springs seemed to pose the highest risk (Table 3) This finding is consistent with previous studies that have identified unprotected water sources as being particularly vulnerable to contamination (Momba et al., 2006; Mushi et al., 2009).

Table 3: Risk Cross Tabulation of the Water Sources

Water Source	**Risk Level**			**Total**
	High	**Low**	**Moderate**	
Protected Springs	15	1	3	19
Protected Wells	1	0	0	1
Rain Water	0	9	2	11
Tap Water	0	8	0	8
Unprotected Springs	43	1	1	45
Unprotected Wells	18	0	0	18
Total	**77**	**19**	**6**	**102**

Table 4: Risk Cross Tabulation of the Administrative Wards

		Risk Level			Total
		High	Low	Moderate	
Ward	Bobaracho	13	3	0	16
	Central	20	3	0	23
	Daraja Mbili	17	0	1	18
	Gekomu	3	5	0	8
	Kanga	1	0	0	1
	Kiamwasi	2	5	0	7
	Kiong'ongi	1	0	1	2
	Nyaura	20	3	4	27
Total		**77**	**19**	**6**	**102**

5.4 Community Hygiene Practices around Drinking Water Sources

On-site water source observation revealed that 61% of the water sources lacked some form of protection. Livestock faeces were observed adjacent to some of the water sources. Evidence of washing clothes close to water sources was recorded at five water sources. Other potential risks included pit latrines located near and mostly upstream of water sources and waste dumps near sources of drinking water. During the study 29 % of the springs visited were protected but most of them were poorly maintained leading to contamination. Most of the wells visited were unprotected and located near pollution sources such as pit latrines.

Wide variations of total coliform were observed within similar water sources but different levels of protection. In samples from unprotected water sources, more than 60% of the water was of high risk.Contamination was attributed to the high level of sewage outflow and indiscriminate dumping of waste. Hygiene conditions and practices that seemed to potentially contribute increased total coliform and Escherichia coli counts included non-protection of water sources. The observation of unprotected water sources and the presence of livestock faeces and evidence of washing clothes close to water sources is concerning. These practices can lead to contamination of the water sources and increase the risk of waterborne illnesses. Therefore, there is a need to educate the local communities on the importance of good hygiene practices and to provide appropriate sanitation facilities to minimize contamination risks. The provision of protected water sources and sanitation facilities can improve the health and well-being of the communities and reduce the incidence of waterborne illnesses.

These findings are consistent with previous studies that have identified poor hygiene practices as a major contributor to water contamination (Mushi et al., 2009; Bain et al., 2014).

6. Conclusion

The geospatial mapping of drinking water sources found that there were a variety of drinking water sources within the Administrative Wards around Kisii Town, including springs, boreholes, and shallow wells, with varying degrees of accessibility and reliability.

The bacteriological quality of drinking water from different sources within the Administrative Wards around Kisii Town was found to vary significantly. Some sources were found to be contaminated with faecal coliforms, while others were found to have low levels of contamination. The findings of this study revealed that average bacterial density in drinking water was relatively high, especially from unprotected water sources, compared with that from protected sources.

The risk of water from different sources within Administrative Wards around Kisii Town was found to vary significantly, with some sources presenting a higher risk of waterborne diseases than others. Pipelines were identified as the safest water source, while springs were found to pose the highest risk of water contamination.

The study found that poor hygiene practices, such as open defecation, laundry activities close to water sources and water sources being near or down slope of latrines were significant contributors to water contamination around the water sources within Administrative Wards around Kisii Town.

7. Recommendations

Based on the findings of this study, the following recommendations were made:

The study recommends that efforts should be made to improve the bacteriological quality of drinking water from unprotected water sources through measures such as regular water testing and treatment.

There is a need for increased investment in the development of protected and reliable water sources to reduce the risk of waterborne diseases. The study suggests that pipelines may be the safest water source and should be prioritized in future water supply projects. Residents should also be encouraged to have safe rainwater roof catchment because these sources were notably safe from the analysis result.

The study recommends that education programs on proper hygiene practices, such as the construction and use of latrines, and the proper disposal of waste, should be implemented to reduce the risk of waterborne diseases.

To reduce the risk of water contamination, The local Public Health department should make a deliberate attempt to conduct health awareness campaigns to sensitize local residents on the quality of the water they are using and on the available household safe water treatment and storage options as these have been shown to significantly improve water quality and reduce waterborne infectious disease risks

Further research is needed on how Geographical Information System (GIS) can be integrated in the water monitoring system to be able to have accurate location of domestic water sources in order to regularly monitor water quality and prevent source contamination.

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