Faecal bacterial contamination of borehole water between points-of-access and points-of-use in Naivasha, Kenya; Public health implication

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Abstract

Microbiological assessment of drinking water at Point of Access (POA), vendors and household levels is a major issue due to realization of the impact of poor microbial water quality on the general public health. The impact is even greater in densely populated areas as in the case of Naivasha. Assessment on the effects of poor handling of drinking water at different domains aims at protecting consumers from waterborne diseases. The study investigated the bacterial water quality levels at different handling domains; borehole POA, vendors and household within three villages (Karagita, Mirera and Kamere). Membrane Filtration Technique (MFT) and heterotrophic Plate Count (HPC) procedure was used in estimating the densities of *Escherichia coli*, intestinal enterococci, *Clostridium perfringens* and heterotrophic bacteria in water samples from all the above domains. In addition, selected physico-chemical parameters were measured in situ using appropriate measuring probes. Data was analyzed using Sigmaplot® analysis software version 12, with α = 0.05. All the water samples from borehole POA, vendors and households had bacterial quality of above the recommended standards for drinking water. Median values for *E. coli*, intestinal enterococci and *C. perfringens* were not significantly different between the sites (P>0.05). Total coliforms and HPC were
significantly different between the site (P<0.05). In conclusion, the study indicates that poor water handling has negative effect on the bacterial quality of drinking water, hence a public health concern. Hygienic water handling practices at both the supply sources and within households storage containers, proper sewerage systems and efficient pre-consumption water purification techniques are recommended.

**Key words:** Bacterial, Boreholes contamination, handling, household, vendors.

**Introduction**

African population has not shown any sign of meeting the 2015 Millennium Development Goal (MDG) on drinking water target. The population without access to improved drinking water sources has even increased by 61 million, from 280 million in 1990 to 341 million in 2006 because the increase in coverage is not keeping pace with population growth (UNICEF & WHO 2008). Water-related diseases continue to be one of the major health problems globally. An estimated 4 billion annual diarrhoeal cases, represented by 5.7% of the global disease burden was recorded in the year 2000 (WHO 2002). This has made it necessary to put in place water quality security measures. Household water security comprise of water availability, good quality, easier accessibility and availability for consumption at household level (Asare, 2004). Water security and sanitation has become a major issue due to realization of the impact of poor microbial water quality on public health. Assessment of drinking water quality at public and private domains aims at ensuring that consumers use water that is free from pathogens of water related diseases (Jensen et al., 2002).

Pollution of water resources in most parts of Kenya is in the rise (Kithiia and Ongwenyi, 1997). Vendors selling water to households or at collection points are common in many parts of Kenya where water scarcity limits access to suitable quantities of drinking-water as the case in Naivasha area. Within this area, vendors use a range of modes of transport to carry drinking-water for sale directly to the consumer (WHO 2009). Other studies have revealed that degradation trends in water quality within Naivasha is due to increased human population density (Okoth and Otieno, 2000; Mavuti, 2003 and Kithiia, 2006). The major source of water for the rapidly-expanding human population within Naivasha area is boreholes. However, increase in anthropogenic activities coupled with rise in human population growth has rendered the quality of water for domestic use unwholesome (Otiang’a and
Oswe 2007). Therefore, there is need for regular water quality analyses at sources and within households.

Regular sampling and analysis provide data on the quality of water, the efficiency of water treatment, the integrity of distribution systems as well as the sanitation status within the households. The range of pathogenic microorganisms is extensive and therefore water is examined for microbiological indicators of contamination (Frahm et al., 2003). The use of indicator organisms is based on the assumption that if they are present then the pathogen may also be present, and if absent then the water is suitable for consumption or pose a lower risk of transmitting WBDs. The principal bacteria indicators are the coliforms bacteria; including total coliforms, faecal coliforms and *E. coli*, the faecal streptococci like intestinal enterococci and *C. perfringens* (Noble et al., 2003). Their presence in drinking water is undesirable, but does not necessarily indicate any health hazard. The faecal coliforms are a group of thermotolerant species which may indicate faecal contamination. The key species of the faecal coliform group is *Escherichia coli* commonly found in the faeces of human and is thus a definitive indicator of faecal contamination (Frahm et al., 2003).

Concern about faecal coliforms densities in water for domestic use is of paramount importance when considering its safety (Japan International Cooperation Agency (JICA), 2003). The densities of faecal contamination indicators may change during the water handling process, for instance from the source to and within the households. The percentage of samples testing positive for indicator bacteria may decrease after collection from highly contaminated sources because of die-off as bacteria compete for limited oxygen and nutrients in the water (Momba & Notshe 2003). Conversely, the percentage of positive samples may increase after water is collected and stored from safe sources because of contamination through hands, unwashed containers and dippers. Where basic sanitation is lacking, there is more likelihood of indicator bacteria from faeces being introduced into stored water (Ologe 1989). Using uncovered water containers is likely to increase water contamination between source and point-of-use as hands are dipped into vessels to scoop a cupful of water (Chidavaenzi et al., 1998).

Various agencies such as World health Organization (WHO), National Environmental Management Authority of Kenya (NEMA-Kenya), United States Environmental protection Agency (US-EPA) and European Framework have outlaid standards for drinking water provision (Table 1). Therefore, concern about faecal coliforms densities in water is of paramount importance when considering the safety of drinking water in Naivasha region.
Ways of finding solutions to the problems of faecal contamination into water sources is very necessary. The objective of this study was to compare the quality of water that is at the borehole points of use against what is at the vendors and household domains as well as confirming whether these qualities meet the drinking water quality guideline by different agencies. It involved determining the densities of total coliforms, *E. coli*, intestinal enterococci, *C. perfringens* and live heterotrophic bacteria using Membrane Filtration Techniques (MFT) and Heterotrophic Plate Count (HPC) Procedure. Some selected physical and chemical parameters were also measured *in situ* from all the water sources sampled. For the household three villages (Karagita, Mirera and Kamere) were studied.

**Table 1: Drinking water quality guidelines by different Agencies**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Authority</th>
<th>WHO</th>
<th>NEMA-KENYA</th>
<th>US-EPA</th>
<th>EU-Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physico-Chemical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>pH units</td>
<td>6.5-8.5</td>
<td>6.5-8.5</td>
<td>≤ 6.5≤9.5</td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td>µs/cm at 20°C</td>
<td></td>
<td></td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>Microbial parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total viable counts at 37°C/ml CFU</td>
<td>not detected/100ml</td>
<td>100</td>
<td>500</td>
<td>20/ml</td>
<td></td>
</tr>
<tr>
<td>Total coliforms CFU</td>
<td>not detected/100ml</td>
<td>shall be absent</td>
<td>&lt;1/100ml</td>
<td>0/100ml</td>
<td></td>
</tr>
<tr>
<td>E. coli CFU</td>
<td>not detected/100ml</td>
<td>shall be absent</td>
<td>&lt;1/100ml</td>
<td>0/100ml</td>
<td></td>
</tr>
<tr>
<td>Enterococci CFU</td>
<td>not detected/100ml</td>
<td>shall be absent</td>
<td>0/100ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphite reducing anaerobes CFU</td>
<td>not detected/100ml</td>
<td>shall be absent</td>
<td>0/100ml</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Materials and Methods**

**Study Area**

Lake Naivasha basin is a freshwater lake in the Rift Valley Province of Kenya (Fig 1). Its watershed covers parts of both the Rift Valley and Central Provinces and it lacks a well-established outlet. It is located in the rain shadow of the Aberdare Range with a mean annual rainfall of about 650 mm, with a heavy rainy season from March to May and a short rainy season in September and October. The mean annual temperature around Lake Naivasha is approximately 25°C, with the highest temperatures from December to March and the lowest in July. The Lake Naivasha watershed is drained by two perennial rivers that enter the lake from the north, the Malewa and Gilgil Rivers, with catchment areas of 1,700km² and 400km²,
respectively. The lake is also drained by other seasonal rivers and streams, including the Kerati River to the north (Mireri, 2005). Karagita is a low income peri-urban settlement situated 6km from the centre of Naivasha Town, next to this internationally renowned Lake Naivasha, a designated Ramsar Site in the Rift Valley Province of Kenya. The community is large and growing fast with a current estimated total population of 54,000 people. This population is distributed in two major blocks; Karagita and neighbouring block Mirera. Karagita is a densely populated slum with a population of 27,000 people. Mirera has 27,000 people that surrounds Karagita and is more sparsely populated. The area is continuing to be built up and using conservative growth rates the population is expected to grow to almost 100,000 people by 2017 and to 173,000 people by 2027. People in 80 percent of the households in the area live on less than US $ 1 dollar each per day and boreholes, rivers and lake are the major sources of water for domestic consumption. (http://www.wsup.com).

![Figure 1: Map of Lake Naivasha; Study sites (adopted from Martin et al., 2001)](image)
Samples Collection and Analysis

Water samples were obtained from boreholes at the points of access (POA), vendors and households from three different villages; Karagita, Mirera and Kamere. Sampling was done on two different days which gave a total of 15 samples from borehole POA, 15 samples vendors, and 25 samples from each of the three villages. Water samples from Borehole- POA were obtained in the same manner the community access the water, where sterilization was not involved. Water samples from vendors were obtained in the same manner it is supplied to the consumers, this was done through the delivery hosepipes and no sterilization was involved prior to sampling. The intension was to give the actual quality within the donkeys’ drawn cats. Water samples from households were obtained from drinking water storage containers. Physical and chemical parameters (temperature, dissolved oxygen, pH and electrical conductivity) of the water being sampled were measured in situ from all the sources using appropriate probes. All the samples were stored in a cool box with ice and transported to Egerton University, Department of Biological science laboratory for analysis.

Samples were analysed within 6-24 hours from sampling time as per the guide line in American Public Health association (APHA), (2005). Aseptic filtration was done separately for each dilution by passing the sample through a membrane filter (47 mm diameter, 0.45μm pore size) on a filtration unit. The filter was placed on the surface of the corresponding culture media. For total coliforms and E. coli counts, filters were placed onto chromocult agar (Merck) plates and incubated at 37 °C for 24 hours. Typical colonies appearing pink and dark blue were counted as total coliforms and E. coli, respectively. For intestinal enterococci counts, filters were placed onto enterococci agar (Merck) plates and incubated at 44 °C for 24-48 hours. Typical colonies appearing pink were counted as intestinal enterococci. For C. perfringens counts, filters were placed onto Tryptose Sulphite Cyclocerine (TSC) agar (Merck) plates. The filters were then placed in an anaerobic jar containing anaerocult strip and incubated at 44 °C for 18-24 hours. Black fluorescent counts of C. perfringens were made under 360nm UV light. For heterotrophic plate counts (HPCs), 1 ml of each sample or its dilution was placed onto 80mm diameter plates with plate count agar and incubated at 37 °C for 48 hours. Colonies forming units (CFUs) were expressed as the number of colonies counted per 1ml. Analysis followed guidelines outlined in (Lawand et al. 1997; Scott et al., 2002; APHA 2005).
Statistical Analysis
Data were analysed using SigmaPlot® analysis software version 12, with $\alpha = 0.05$. Since most of the data were neither normally distributed nor had equal variances, so data are reported as medians with 25th and 75th percentiles, and non-parametric tests (ANOVA on Ranks and Turkey tests) were used to test for significant differences.

Results

Physical and Chemical Parameters
All the water types sampled (borehole POA, vendors, and households in Karagita, Mirera and Kamere villages) had temperature median values ranging between 20.50°C and 22.65°C. Values for dissolved oxygen (DO) ranged between 2.8mg/l to 6.08mg/l. pH values ranged between 8.17 and 8.80 while electrical conductivity values had a range of between 369.00$\mu$s/cm and 1494.00$\mu$s/cm (table 2). Borehole access had the highest temperature values than all the other sources, water from vendors gave the lowest DO and percentage DO values while Ph values were generally similar for all the sources. Electrical conductivity values were found to be closer to the one from boreholes POA in all the other sources except in household in Kamere village (Table 2).

For all these water types, all the physical and chemical parameters showed significant variation between the water types (borehole POA, vendors, and households and Karagita, Mirera and Kamere), $P=0.003$, $P<0.001$, $P<0.001$, $P<0.001$ and $P<0.001$ respectively for temperatures, DO, % saturation of DO, pH and Conductivity (Table 2). All these values from all the water types were within the recommended range for drinking water quality standards by the above agencies, pH values were within the acceptable range of 6.6-8.5 as recommended by US-EPA. Conductivity values were also within the acceptable limit (<2500 $\mu$s/cm) by the EU-framework standard.
Table 2: Median (25%, 75% interval) of water quality parameters within different water handling domains

<table>
<thead>
<tr>
<th>Domains</th>
<th>N</th>
<th>Temperature (°C)</th>
<th>DO (mg/l)</th>
<th>%DO</th>
<th>pH</th>
<th>Conductivity (µs/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH POA</td>
<td>16</td>
<td>22.7 (22.5, 3.5)A</td>
<td>4.3 (4.2, 4.8)AB</td>
<td>65.9 (64.7, 72.3)A</td>
<td>8.2 (8.1, 8.4)AC</td>
<td>1494.0 (1437.0, 1766.0)A</td>
</tr>
<tr>
<td>Vendors</td>
<td>15</td>
<td>20.5 (19.2, 22.2)B</td>
<td>2.9 (2.0, 3.3)B</td>
<td>35.7 (30.1, 47.8)B</td>
<td>8.2 (7.2, 8.2)B</td>
<td>1178.0 (458.0, 1305.0)B</td>
</tr>
<tr>
<td>HH Karagita</td>
<td>25</td>
<td>22.2 (20.6, 23.6)AB</td>
<td>6.1 (4.3, 6.5)A</td>
<td>87.3 (62.1, 95.1)B</td>
<td>8.2 (8.3, 8.6)A</td>
<td>1292 (1285, 1597)A</td>
</tr>
<tr>
<td>HH mirera</td>
<td>25</td>
<td>21.7 (21.4, 23.8)A</td>
<td>6.1 (4.7, 6.6)A</td>
<td>80 (66.8, 94.6)B</td>
<td>8.2 (7.6, 8.4)BC</td>
<td>1140.0 (1119.0, 1149.0)B</td>
</tr>
<tr>
<td>HH Kamere</td>
<td>25</td>
<td>21.2 (20.3, 23.0)AB</td>
<td>6.1 (3.5, 6.8)A</td>
<td>87.4 (44.3, 97.9)B</td>
<td>8.2 (7.5, 8.2)BC</td>
<td>369.0 (190.0, 1317.0)B</td>
</tr>
</tbody>
</table>

P-Values: 0.003 < 0.001 < 0.001 < 0.001 < 0.001

Where ANOVAs on Ranks were significant (P<0.05), Tukey tests were performed to determine sites that were significantly different (indicated with different letters in a column)
Microbiological Parameters in Water at Different Handling Domains

Based on handling by the vendors and at the households’ domain, it was noted that the microbiological quality of the water was poorer within the households and vendors as compared to the quality at the borehole point of access from where the majority of vendors and household obtained. Microbiological values were also compared to the standard values for drinking water quality by the local and international agencies; NEMA-Kenya, WHO, US-EPA and the European framework. From the samples obtained from all the water types, *E. coli* had median values ranging between 0.00-8.00cfu/100ml with vendors and households in Mirera villages giving higher median values than other water types (Figure 2). Except in households from Karagita and Kamere villages, all the other water types had values higher than the recommended values for drinking water quality standards of zero detection per 100ml of water by the above agencies. However, there was no significant variation in *E. coli* values between the water types, P=0.571. Median values for total coliforms ranged between 25.75cfu/100ml to 48.00cfu/100ml with vendors and household giving higher median values than borehole POA (Figure) 3. All the water types under this study (borehole POA, vendors, and households and Karagita, Mirera and Kamere) had values higher than the recommended values for drinking water quality standards of zero detection per 100ml of water by the above agencies. There was significant variation in total coliforms values between the water types, P<0.001.

![Figure 2: Densities of E. coli in different water handling domains](image-url)

(The boxes span from 25th and 75th percentiles, with the median in between. The bars with whiskers span from estimated 10th and 90th percentile values and markers indicate out-liers. Bars with the same corresponding letters on top are not significantly difference at P>0.05.)
Median values for intestinal enterococci ranged between 25.75 cfu/100ml to 48.00 cfu/100ml with household giving higher values than the vendors and borehole POA (Figure 4). All the water types under this study (borehole POA, vendors, and households and Karagita, Mirera and Kamere) had values higher than the recommended values for drinking water quality standards of zero detection per 100ml of water by the above agencies. There was no significant variation in intestinal enterococci values between the water types, P=0.207.
Median values for *Clostridium perfringens* were all zero for all the water types (Figure 5). All the water types under this study (borehole POA, vendors, and households and Karagita, Mirera and Kamere) had values within the recommended values for drinking water quality standards of zero detection per 100ml of water by the above agencies. There was no significant variation in *C. perfringence* values between the water types, $P=0.878$. 

*Figure 4: Densities of intestinal enterococci in different water handling domains*
Faecal bacterial contamination of borehole water between points-of-access

Vendors

Density of C. perfringens (cfu/100ml)

0

20

40

60

80

100

120

140

Borehole Vendors Karagita Mirera Kamere

Water handling domains

Figure 5: Densities of C. perfringens in different water handling domains

(The boxes span from 25th and 75th percentiles, with the median in between. The bars with whiskers span from estimated 10th and 90th percentile values and markers indicate outliers. Bars with the same corresponding letters on top are not significantly different at P>0.05).

Median values for heterotrophic bacteria enumerated through Heterotrophic plate count procedure had a range of between 350.00cfu/1ml to 560.00cfu/1ml with vendors and households giving higher values than borehole POA as in figure 6. All the water types under this study (borehole POA, vendors, and households and Karagita, Mirera and Kamere) had values above the recommended values for drinking water quality standards of less than 100cfu detection per 1ml of water by the above agencies. There was significant variation in HPC values between the water types, P=0.013.
Discussion

The results obtained on physical and chemical parameters under this study were all within the recommended range for drinking water quality standards by regulation agencies, pH values were within the acceptable range of 6.6-8.5 as recommended by US-EPA. Conductivity values were also within the acceptable limit (<2500 μs/cm) by the EU-framework standard. Significant variation that occurred in all the physical and chemical parameters under this study based on the water types (borehole POA, vendors, and households and Karagita, Mirera and Kamere) indicated that handling at different domains were at different degrees and hence impacted differently on the physical chemical variables. This was in agreement with the study in Kurdistan region which indicated that the physic-chemical properties of all bottled water samples were within the international guidelines of bottled water and that sun light exposure and temperature of storing cause changes in all physico-chemical properties of water in the plastic bottle (Sulaiman et al., 2011).
High *E. coli* median values recorded in waters from vendors and households in Mirera than water from borehole POA and other households was an indication of high incidences of exposer of water to recent faecal contaminants mostly from human origin. However, absence of significant variation in *E. coli* between the different water types was an indication for all the domains, poor handling procedure could be contributing to *E. coli* loads into the water in more or less the same manner. The result on *E. coli* for this study was in agreement with a study which had found out that the quality of water declines because of recontamination in the home, and further suggested that efforts to improve source water quality and sanitation be maintained at all levels of water provision (Karen *et al.*, 2008). In addition, it had been found that poor house water storage practices may also have a negative impact on some of the available water treatment measures there by increasing the contaminants, as was the case in in homes within the Dominican Republic (Holt, 2009). High total coliform median values recorded in waters from vendors and households than water from borehole POA was an indication of high incidences of exposure of water to faecal contaminants and or other organic materials as it moves along the chain of supply; boreholes to vendors to households. In addition, significant variation in total coliforms between the different water types showed the presence of poor water handling procedures of different degree at different levels. A study in Khartoum had also found out that about half of the storage tanks had been contaminated with microbes and suggested secure storage coverage as a solution to contamination (Zohoor *et al.*, 2008).

High intestinal enterococci median values recorded in waters from vendors and at the households than that from the borehole POA was an indication of high incidences of exposer of water to faecal contamination, mostly from non-human origin. However, absence of significant variation in intestinal enterococci between the different water types was an indication that at all the domains, poor handling procedure could be contributing to intestinal enterococci loads into the water in more or less the same manner. Low *C. perfringens* median values recorded in all the water types were an indication of low density of *C. perfringens* in faecal contaminants getting into water. In addition, absence of significant variation in *C. perfringens* between the different water types was an indication that at all the domains, poor handling procedure could as well be contributing to *C. perfringent* loads into the water in more or less the same manner. High HPC median values recorded in waters from vendors and households than water from borehole POA was a show of high incidences of exposure of water to organic contaminants as it moves along the supply chain; boreholes to vendors to households. In addition, significant variation in HPC between the different water types was
an evidence of the presence of poor water handling procedures of different degree at different levels. Similar studies have found out that improper maintenance and cleaning practices may cause an increase in HPCs, in treated water storage receptacles and this could be caused by improper cleaning, moving of the filter, placing the filter element on the ground, putting dirty hands inside the plastic container, and drying the container using a dirty cloth (Murphy et al., 2010). The results obtained on *E. coli*, total coliforms, intestinal enterococci and HPC under this present study were all above the recommended value for drinking water quality standards by regulation agencies, hence calling for appropriate treatment measures before consumption.

The result on microbial parameters were also found to be the as the results by several other studies. One such study had found out that the percentage of positive samples increased after water was collected and stored from safe sources because of contamination through hands, unwashed containers and dippers (Momba & Notshe, 2003). Therefore based on this reasoning, where basic sanitation is lacking, there is more likelihood of indicator bacteria from faeces being introduced into stored water (Ologe, 1989). Using uncovered water containers is also likely to increase water contamination between source and point-of-use as hands are dipped into vessels to scoop a cupful of water (Chidavaenzi et al., 1998). There are also a number of health concerns associated with water supplied to consumers by water vendors. These include concern regarding inadequate treatment or poor transport using inappropriate containers, which can result in contamination (WHO, 2002).

Since everyone consumes water from one source or another, consumers often play important roles in the collection, treatment and storage of water. Consumer actions may help to ensure the safety of the water they consume and may also contribute to improvement or contamination of the water consumed by others. Consumers have the responsibility for ensuring that their actions do not have an adverse impact on water quality (WHO, 2009). In most countries, there are populations whose water is derived from household sources, such as private wells and rainwater. In households using non-piped water supplies, appropriate efforts are needed to ensure safe collection, storage and perhaps treatment of their drinking-water. In some circumstances, households and individuals may wish to treat water in the home to increase their confidence in its safety. This would be relevant where community supplies are absent or where community supplies are known to be contaminated or causing waterborne disease. Public health surveillance or other local authorities may provide guidance to support households and
individual consumers in ensuring the safety of their drinking-water. Such guidance is best provided in the context of a community education and training programme (WHO, 2009).

Other additional similar studies have been carried out in other parts of the world and also found out that poor handling procedures are detrimental to the quality of domestic water. Maraj et al., (2006) found out that both ground-tank and stand-pipe water deteriorated during storage due to poor handling, although ground-tank water was of better quality than stand-pipe water. Another study on water used from plastic household container had found out that increased microbiological contamination is associated with biofilm. The biofilm harbours heterotrophic bacteria, total coliforms and C perfringens, however, E. coli could not be associated directly with the levels of biofilm in containers but rather appears to be introduced intermittently from the ambient domestic environment. When dislodged with the biofilm, these bacteria contributed substantially to the deterioration of the microbiological quality of supplied water stored in plastic containers (Jagals et al., 2003). Another study in Peru found out that Post-source contamination increased successively through the steps of usage from source water to the point of consumption. In addition, boiling failed to ensure safe drinking water at the point of consumption because of easily contaminated containers and poor domestic hygiene and hence hygiene education, better point-of-use treatment and storage options, and in-house water connections were recommended to be urgently implemented (William et al., 2007).

Conclusions and Recommendations

Based on the findings of this study, the conclusion drawn is that water from all the borehole point of access sources within the Lake Naivasha basin are of poor bacteriological quality. The poor human water handling practices within Lake Naivasha basin result to further degradation of the bacterial quality of domestic water at the collection points and within the households. Determination of the pathogenic bacteria on water is critical due to its implications on public health.

Several recommendations are drawn from the result of this study. They are necessary in improving the quality of water available for human consumption and reducing the incidences of waterborne disease outbreaks. These are;

1. Awareness creation on personal and environmental hygiene including maintenance of high sanitation standards in water distribution points as well as in water storage and distribution containers.
2. Need to put in place proper sewage disposal and treatment measures to reduce the amount of raw sewage that finds its way into the water sources.
3. Need to supply the communities with clean piped water at their households to keep the population away from the surface sources (rivers and lake). This can assist in protecting these water sources from further quality degradation and pollution.
4. Availing and emphasizing the use of affordable, cheap and locally available and environmentally friendly point of use/household water treatment approaches. These include solar radiation disinfection using water pasteurization kits. This is required in rural and informal urban settlement (slums) as it is the case in Lake Naivasha basin where water is obtained from public standpoints, rivers, lake or from resellers (vendors).

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