Analysis of Microbial Quality of Drinking Water in Njoro Sub-county, Kenya

Article · October 2019
DOI: 10.12691/jephh-5-1-3

3 authors, including:

Philip Kirianki
University of Rostock
3 PUBLICATIONS **23** CITATIONS
SEE PROFILE

Kiruki Sila
Chuka Universit
9 PUBLICATIONS **93** CITATIONS
SEE PROFIL

Journal of Environment Pollution and Human Health, 2017, Vol. 5, No. 1, 15-21
Available online at http://pubs.sciepub.com/jephh/5/1/3

DOI:10.12691/jephh-5-1-3

Analysis of Microbial Quality of Drinking Water in Njoro Sub-county, Kenya

Kirianki PR[1,*], Othira JO[1], Kiruki S[2]

1 Department of Biochemistry and Molecular Biology, Egerton University, 536-21115, Njoro, Kenya
2 Department of Physical sciences, Chuka University, 109-60400, Chuka, Kenya
*Corresponding author: philipkirianki@gmail.com

skiruki@chuka.ac.ke

Abstract

Drinking water should be free of microbial pathogens so as to be regarded as potable water and safe for drinking. However, water is prone to fecal contaminants which are the sources of gastrointestinal illnesses. In Njoro Sub-county, river Njoro and rain water are the primary sources of water which also reduces during dry seasons. Other water sources include boreholes, dams, springs and wells while in other cases, the residents store water in household storage containers for future uses. In this study, various water sources and water stored in different containers in Njoro Sub-County was analyzed for its microbial quality. Various microbial parameters such as total viable colony counts (TVCC), total coliforms (TC) and fecal coliforms (FC) were evaluated by use of the culture methods. Most of the water sources were contaminated. TVCC ranged from 0.47 to 1.76 CFU/1mL in water sources and 0.48 to 2.04 CFU/1mL in domestic storage containers. TC was in the range of between 0.30 to 1.89 CFU/100mL in water sources and 0.59 to 2.47 CFU/100mL in domestic storage containers. The mean FC in water sources ranged from 0.10 to 1.68 CFU/100mL and from 0.81 CFU/100mL domestic storage containers. Therefore frequent water testing should be performed by water authorities as recommended by WHO. At households, the people should employ various water treatment methods and practice safe water handling so as to avoid gastrointestinal infections.

Keywords: *coliforms, water quality, contamination*

Cite This Article: Kirianki PR, Othira JO, and Kiruki S, "Analysis of Microbial Quality of Drinking Water in Njoro Sub-county, Kenya." *Journal of Environment Pollution and Human Health*, vol. 5, no. 1 (2017): 15-21. doi: 10.12691/jephh-5-1-3.

1. Introduction

Microbiological quality of water is measured by the use of indicator organisms such as TVCC, TC and FC bacteria [1]. TVCC are also known as total plate count, heterotrophic plate count or pour plate and are widely used in the measurements of heterotrophic microorganisms in water meant for drinking purposes. The heterotrophs consist of microorganisms such as yeasts, molds, and bacteria which needs external sources of organic carbon in order to grow. Some members of this group are opportunistic pathogens and can cause aesthetic and non-life-threatening diseases especially in immunosuppressed people as well as children [1,2].

TVCC therefore, accesses the formation of colonies on a culture media and hence it is a measure of the overall bacteriological quality of drinking water in both public as well as private water systems. The level or recoverability of heterotrophic organisms using this method depends on the type of media used, the culture temperatures, age of the water sample and the duration of the culture. As a result, high numbers of TVCC bacteria in a distribution system might be a result re-growth of bacteria that resisted treatment or alternatively those that were injured during treatment have recovered. In this case, bacterial re-growth can lead to devastating effects such as corrosion of pipes and increased growth of slime and hence the need for disinfectants [3].

TC comprises of bacterial species of fecal origin as well as other non-fecal bacteria groups [4]. These microorganisms are indicative of the general hygienic quality of the water and potential risk of infectious diseases from the water. Since it is not economical and practical to test for each and every microorganism, the TC indicator tests are done because their presence indicates the presence of pathogenic groups of bacteria.

Coliform bacteria should not be detected in treated water supplies and, if found, suggest inadequate treatment, post-treatment contamination, or excessive nutrients. Thus tests for TC bacteria serves as an indicator of both treatment efficiency and integrity of the distributing system [5].

FC bacteria are associated with intestinal tract and hence are released to the environment by fecal contamination by animals as well as human fecal excreta [6]. They are not necessarily pathogenic but their presence is indicative of the presence of pathogenic bacteria of fecal origin. They can enter water bodies through direct release of waste from animals and untreated human sewage [7]. Additionally, agricultural activities like the application of manure allow animal wastes to wash into water bodies [8]. When people consume fecally contaminated water, they stand high chances of suffering from gastroenteric infections such as diarrhea. Children under the age of 5 years and the immunosupressed are the major victims of diarrhea. This calls for the frequent monitoring of the drinking water sources for their microbial quality [9]. In a study that investigated the contamination chain of domestic water in the Njoro Township in Kenya [10], the *E. coli* (a fecal coliform) density was in the range of 0–220CFU/100 mL (point of collection) and 0–520CFU/100 mL (low-income households and vendors). No previous studies on water quality have been done in Mauche, Maunarok and Kihingo locations prior to this study. However, a study had been carried out on the fluoride contamination of water in Lare location [11]. More studies in Njoro location have been done on the microbial quality of river Njoro both upstream and downstream and found a high level of microbial contamination [9]. A different study in Njoro Township (Njoro location) was aimed at determining the microbial quality of drinking water between the high income and low income households [10]. Therefore, this study is a conclusive and more informative study on the microbial quality of drinking water in Njoro Sub County.

Since no water quality studies have previously been documented in Mauche, Kihingo and Maunarok locations, this study sought to determine the overall microbial quality of drinking water in Njoro Sub County. Previous studies in Lare location were based on the fluoride levels while most studies in Njoro location have mainly focused on river Njoro. This study, therefore, sought to determine the microbial quality of drinking water from various sources and water stored inside various household storage containers within the five locations in Njoro Sub-County.

2. Materials and Methods

Study area

Njoro Sub-county is located at an elevation of 1 600 to 2 000m above sea level and about 20km Southwest of Nakuru town in the Kenyan Rift Valley Province. The region is classified as semi-arid with a total annual rainfall that ranges from 500mm in the lowlands to 1,800mm in the highlands and occurring in two seasons namely the long rains from March to April and the short rains from October to December. The Njoro River and rain water are the major sources of water but its volume reduces during dry seasons. Thus other common sources of water in this area include boreholes, wells, dams and springs. The

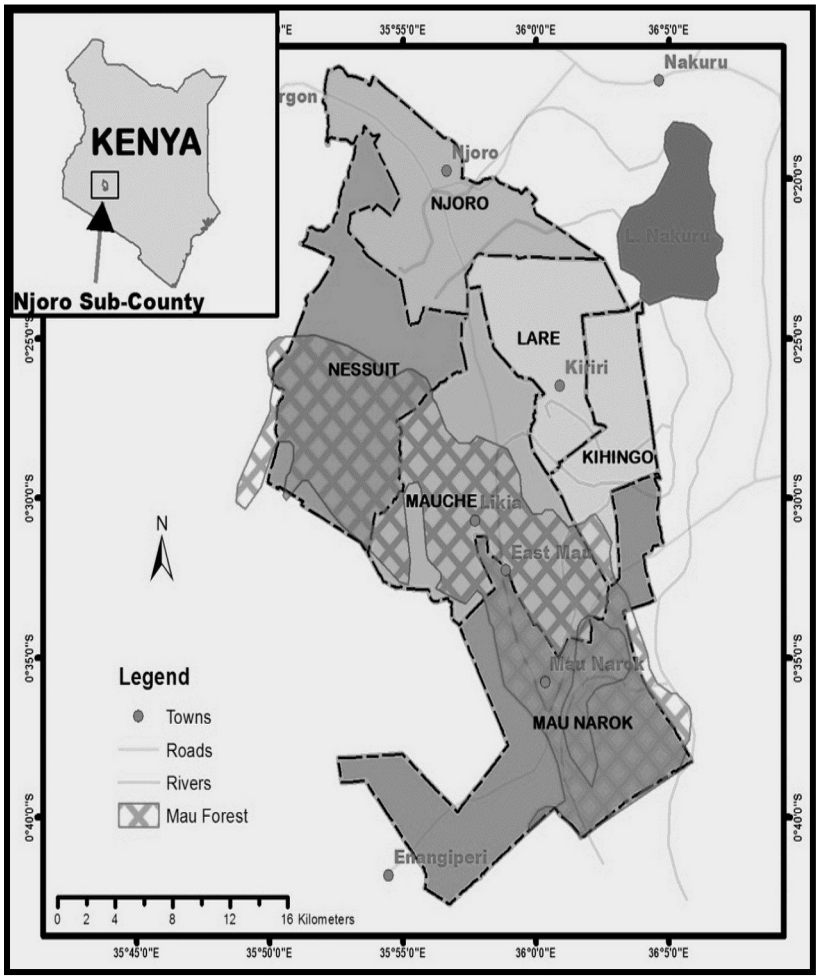

Figure 1. Map of study area

inconsistency in water supply in dry seasons in this area also requires that people store water in household containers for future use. The Sub-County is divided into 5 administrative locations namely: Njoro, Lare, Kihingo, Maunarok and Mauche (Figure 1) with a total population of 188,124 people. The mainstay of the economy in this area is agri-based industries including vegetable and milk processing, large-scale maize, wheat and barley farming and light manufacturing industries such as timber milling, canning, and quarrying.

Sample collection

Simple random sampling was used to select the participating villages and water was collected. The samples were collected by visiting the homesteads at random and taking a sample from any domestic container that had stored water. The water from sources was collected from any source that the researchers came across within the 5 locations of the study area. Sterile 500mL plastic bottles were used for sample collection. The sample bottle was rinsed with the water sample three times before taking the sample. Each of the samples was replicated three times during sample collection. Water samples from five locations of Njoro Sub-County were collected from the river Njoro, springs, water vendor kiosks, household storage containers, taps, wells and boreholes. Samples were collected directly into the sample container and transported immediately on ice to the Egerton University Limnology laboratory for further analysis within 6 hours of sample collection.

Improved and unimproved water sources

An improved water source is a type of water source which as a result of a construction or intervention programs, is protected from external sources of contamination. In this study, the encountered and sampled improved water sources were storage tanks, piped water/taps, boreholes, protected wells and protected springs. Unimproved water sources are those that are not protected in any way from external contaminants like fecal matter. In this study, the common unimproved water sources that were found and sampled were river Njoro, dams, unprotected wells and unprotected springs.

Domestic/household storage containers

These are the containers that are used to store water inside the houses for future use in domestic settings. This form of storage is common in areas where water supply is not constant and hence the sources are not quite reliable. In this study therefore, all the containers such as jerry cans, jugs, cups, sufurias, pots and so on that were found to having water in them were sampled three times and the sample classified as household storage container as shown in the results tables.

Data analysis

All the data generated during this study were coded and entered into MS Excel 2010 and imported into SAS version 9.1 for analysis. The means and standard errors were determined and recorded. One way Analysis of Variance was carried out to test whether the differences between the means were significant or not while the level of significance was determined using the Least Significant Design (LSD) at $\alpha=0.05$. The coliform counts were transformed to $\log_{10}$ and the results presented in tables.

2.1. Determination of TVCC in Drinking Water

TVCC test was done using the standard pour plate method according to the method of [12] (Figure 2A). Briefly, 1mL of the water sample was aseptically transferred into clearly marked sterile Petri dishes. A volume of 15mL of sterile molten Plate Count Agar (PCA) at room temperature was added to each of the Petridishes and thoroughly swirled to facilitate sample distribution in the media. The plates were then left to solidify at room temperature, inverted upside down and incubated for 24 hours at 37°C. The colonies were recorded as colony forming units per ml (CFU/1mL).

2.2. Total Coliform Counts (TC)

TC was enumerated by membrane filtration technique method (Stuart, Bibby scientific, UK). A sterile 0.45µm, 47mm membrane filter (Sartorius, Germany) was placed on a filter funnel. A volume of 10mL of each water sample was added to a membrane and the vacuum pump turned on. After the water was passed through the filter, it was maintained in the vacuum until all liquid had passed. The filter was then transferred using a sterile forceps to a 50mm disposable Petri dish containing Eosin Methylene Blue (EMB) agar. Each funnel was rinsed with 20mL distilled water between each water sample. All Petri dishes were incubated upside down in an incubator for 24 ± 2 hours at 37°C. All samples were analyzed by counting the blue and pink colonies under a colony counter (Acculite, Fisher, USA) and recorded as CFU/100mL as shown in Figure2B.

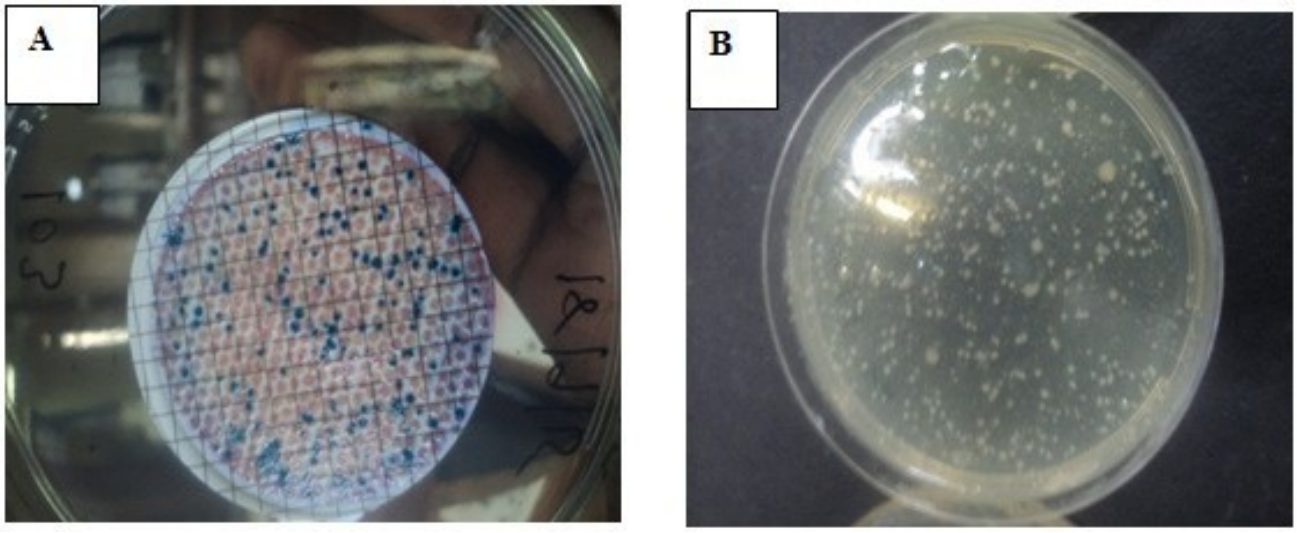

Figure 2. TC (A) and TVCC (B) colonies after incubation in EMB and PCA media respectively

3. Results

The samples were randomly collected leading to unequal sample sizes among the 5 locations in the study area. As such, during sampling, some water sources were not found or were absent in some locations and hence not available for sampling. Moreover, some domestic storage containers were absent or were not found to be having any water during sampling and they were not sampled. The results for the sources and storage containers that were absent or were not having any stored water are indicated as (-) in the tables since there was no data collected for analysis. The results obtained in this study were compared to the WHO recommended levels for drinking water quality as indicated in the appendices section.

3.1. TVCC in Water Sources and Water in Various Household Storage Containers

All the sampled water sources were contaminated with TVCC which was in the range of $\log_{10}$ 0.48±0.12 (unprotected wells in Njoro) to 1.76±0.05 CFU/1mL (taps in Maunarok and boreholes in Mauche) as shown in Table 1. In the sampled household storage containers, the highest $\log_{10}$ mean of TVCC CFU/1mL were recorded in buckets used to store drinking water in Lare (2.04±0.01 CFU/100mL) while lowest means were in sufuria in Mauche (0.48±0.09 CFU/100 mL) as indicated in Table 2.

3.2. TC Counts in Water Sources and Water in various Household Storage Containers

All the sampled water sources in Njoro Sub-County were contaminated with TC as shown in Table 3. The mean $\log_{10}$ TC CFU/100 mL in the water sources were highest in tanks in Mauche (2.12±0.27 CFU/100 mL) and lowest in taps in Mauche (0.30±0.00 CFU/100 mL) and in unprotected wells in Njoro (0.30±0.07 CFU/100mL). All the sampled household containers were contaminated with TC which ranged from $\log_{10}$ 0.59±0.09 CFU/100mL (jerry cans in Njoro) to 2.47±0.23 CFU/100mL (buckets in Lare) as shown in Table 4.

Table 1. Mean $\log_{10}$TVCC CFU/1mL for water source types in Njoro Sub-County

	WATER SOURCE	KIHINGO mean±SE (n = number of samples)	LARE mean±SE (n = number of samples)	MAUCHE mean±SE (n = number of samples)	MAUNAROK mean±SE (n = number of samples)	NJORO mean±SE (n = number of samples)
Unimproved sources	River	-	-	-	-	1.18±0.03[a] (n=3)
	Springs	-	-	-	-	-
	Wells	-	-	-	-	0.48±0.12[a] (n=3)
	Dams	-	-	-	-	-
Improved sources	Springs	-	-	-	-	-
	Taps/piped water	-	1.14±0.18[a] (n=9)	0.70±0.14[a] (n=3)	1.76±0.05[a] (n=3)	1.06±0.16[a] (n=12)
	Tanks	1.20±0.18[a] (n=9)	0.63±0.15[a] (n=6)	0.94±0.29[a] (n=9)	1.31±0.14[a] (n=15)	-
	Boreholes	0.69±0.14[a] (n=6)	-	0.48±0.13[a] (n=3)	-	-
	Wells	1.47±0.11[a] (n=6)	-	-	-	-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

Table 2. Mean $\log_{10}$ TVCC CFU/1mL for domestic containers in Njoro Sub-County

WATER CONTAINER	KIHINGO mean±SE (n = number of samples)	LARE mean±SE (n = number of samples)	MAUCHE mean±SE (n = number of samples)	MAUNAROK mean±SE (n = number of samples)	NJORO mean±SE (n = number of samples)
Gallons	1.00±0.02 (n=3)	-	-	-	-
Jugs	-	-	1.08±0.14 (n=3)	-	-
Cups	-	-	-	-	-
Jerry cans	-	1.07±0.17[a] (n=6)	-	1.20±0.30 (n=6)	0.93±0.08 (n=6)
Clay pots	-	-	1.40±0.11 (n=3)	-	-
Buckets	-	2.04±0.01[a] (n=3)	-	-	-
Sufurias	-	-	0.48±0.09 (n=3)	-	-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

Table 3. Mean $\log_{10}$ TC counts/100mL for water source types in Njoro Sub-County

WATER SOURCE		KIHINGO mean±SE (n = number of samples)	LARE mean±SE (n = number of samples)	MAUCHE mean±SE (n = number of samples)	MAUNAROK mean±SE (n = number of samples)	NJORO mean±SE (n = number of samples)
Unimproved sources	River	-	-	-	-	1.40±0.03[a] (n=3)
	Springs	-	-	-	-	-
	Wells	-	-	-	-	0.30±0.02[a] (n=3)
	Dams	-	-	-	-	-
Improved sources	Springs	-	-	-	-	-
	Taps/piped water	-	1.59±0.50[a] (n=9)	0.30±0.07[a] (n=3)	1.64±0.49[a] (n=3)	0.90±0.22[a] (n=12)
	Tanks	1.87±0.03[a] (n=9)	1.56±0.11[a] (n=6)	2.12±0.27[a] (n=9)	1.73±0.13[a] (n=15)	-
	Boreholes	1.11±0.41[a] (n=6)	-	0.60±0.21[a] (n=3)	-	-
	Wells	1.89±0.08[a] (n=6)	-	-	-	-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

Table 4. Mean $\log_{10}$ TC CFU/100mL for domestic containers in Njoro Sub-County

WATER CONTAINER	KIHINGO mean±SE (n = number of samples)	LARE mean±SE (n = number of samples)	MAUCHE mean±SE (n = number of samples)	MAUNAROK mean±SE (n = number of samples)	NJORO mean±SE (n = number of samples)
Gallons	0.95±0.31 (n=3)	-	-	-	-
Jugs	-	-	2.09±0.21 (n=3)	-	-
Cups	-	-	-	-	-
Jerry cans	-	1.42±0.27[a] (n=6)	-	1.76±0.18 (n=6)	0.59±0.09 (n=6)
Clay pots	-	-	2.09±0.39 (n=3)	-	-
Buckets	-	2.47±0.23[a] (n=3)	-	-	-
Sufurias	-	-	1.74±0.08 (n=3)	-	-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

Table 5. Mean $\log_{10}$ FC CFU/100mL for water source types in Njoro Sub-County

WATERSOURCE		KIHINGO mean±SE (n = number of samples)	LARE mean±SE (n = number of samples)	MAUCHE mean±SE (n = number of samples)	MAUNAROK mean±SE (n = number of samples)	NJORO mean±SE (n = number of samples)
Unimproved sources	River	-	-	-	-	0.00±0.00[a] (n=1)
	Springs	-	-	-	-	-
	Wells	-	-	-	-	0.00±0.00[a] (n=3)
	Dams	-	-	-	-	-
Improved sources	Springs	-	-	-	-	-
	Taps/piped water	-	1.08±0.12[a] (n=9)	0.00±0.00[a] (n=3)	1.43±0.05[a] (n=3)	0.00±0.00[a] (n=12)
	Tanks	0.10±0.02[b] (n=9)	0.64±0.11[a] (n=6)	0.00±0.00[a] (n=9)	0.97±0.28[a] (n=15)	-
	Boreholes	0.00±0.00[b] (n=6)	-	0.00±0.00[a] (n=3)	-	-
	Wells	1.68±0.07[a] (n=6)	-	-	-	-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

Table 6. Mean $\log_{10}$ FC CFU/100mL for domestic storage containers in Njoro Sub-County

WATER CONTAINER	**KIHINGO** mean±SE (n = number of samples)	**LARE** mean±SE (n = number of samples)	**MAUCHE** mean±SE (n = number of samples)	**MAUNAROK** mean±SE (n = number of samples)	**NJORO** mean±SE (n = number of samples)
Gallons	0.00±0.00 (n=3)	-	-	-	-
Jugs	-	-	0.00±0.00[a] (n=3)	-	-
Cups	-	-	-	-	-
Jerry cans	-	0.00±0.00[a] (n=6)	-	0.81±0.25 (n=6)	0.00±0.00 (n=6)
Clay pots	-	-	0.00±0.00[a] (n=3)	-	-
Buckets	-	0.00±0.00[a] (n=3)	-	-	-
Sufurias	-	-	0.00±0.00[a] (n=3)		-

SE = standard error - Not tested since no sample of that type was found for collection during sampling Means followed by the same small letter in a column are not significantly different at 5% LSD.

3.3. FC Counts in Water Sources and Water in Various Household Storage Containers

The mean $\log_{10}$ FC CFU/100mL of the sampled water sources in Njoro Sub County is presented in Table 5 whereby the counts ranged from 0.00 to 1.68±0.07 CFU/100mL. In the sampled household containers, all the containers had mean $\log_{10}$ FC counts of 0.00CFU/100mL apart from jerry cans in Maunarok (0.81±0.25CFU/100mL) respectively (Table 6).

4. Discussion

The results obtained for microbial quality in Njoro Subcounty, indicated that the drinking water sources were microbially contaminated. The high concentrations of TVCC and TC were an indication of the load of contamination in water otherwise meant for drinking purposes. A similar study on microbial analysis of stored and treated drinking water in Nakuru North Sub-county found that 35% (189/540) of the water samples were positive for TC (51.8%), *E. coli* (32.3%) and *Salmonella* (15.9%) respectively [13]. This indicated that the water from sources and storage household containers in Nakuru North-sub-county did not meet the microbial quality guidelines by WHO in order to qualify for drinking purposes. Continuous changes in the water flow rate at sources and domestic containers could be responsible for the increased HPC due to increased microbial growth. Based on the various tested parameters and the different locations, there are sources and containers that were less contaminated and hence recommended for use. However generally, this study indicated that the clay pots, sufuria and some jerry cans were safe for storage while the protected wells, taps and boreholes were the recommended sources of water since they recoded low to no microbial counts.

The low in TVCC, TC and FC levels in household storage containers as compared to sources was probably due to the use of treatment methods such as boiling and chlorination. A similar trend of decreased TC at households was observed in a study to determine the bacteriological quality of drinking water in Kibera slums in Nairobi. This study found that 10% of outhouse waters and a further deterioration of about 95% of household's storage containers were contaminated with fecal coliforms [14]. On the other hand, an increase in the bacterial counts at households as compared to the water sources might be linked to further deterioration of drinking water with fecally contaminated hands or objects. A study conducted in Vietnam also found off-premises piped sources to contain more fecal contamination than on-premises piped sources, with evidence of similar stored water quality for both source types [15]. Additionally, there is a possibility of contamination of water by vendors or during transportation from off premises to homesteads, during storage as well as handling [10]

Microbial contamination in storage containers may be due to lack of regular cleaning, defects on the pipe-lines or contamination during distribution. The trends of storing water for long in households can result to a possibility of fecal contamination of maybe initially good-quality drinking water. Such contamination can arise from dipping of fecally contaminated hands or utensils in the storage containers especially by children. This form of contamination pathway at the household is independent of pollution at the source because the source might be free from contamination. These findings of this study are similar to those of another study on the bacteriological quality of drinking water sources in Njoro Division, which indicated that the fecal coliform counts in the Njoro River were higher than the WHO guidelines [10]. Another study found that Njoro River was highly contaminated with indicator bacteria *E. coli* [9]. Therefore the increased concentration of TVCC, TC and FC is likely to result to increased diarrheal episodes among the local communities. The children, elderly and immunosuppressed people are most affected from diarrhea due to low immunity. The reports from Njoro Health Centre and Nakuru Provincial General Hospital (NPGH) in Kenya indicate a high prevalence of undiagnosed diarrhea which was closely linked to consumption of pathogen-polluted waters [16].

One of the major causes of diarrheal diseases is consumption of microbe contaminated drinking water. These diarrheal diseases weakens the immune system leading to higher risk of other diseases which present themselves as opportunistic infections [12]. The results obtained for microbial quality in Njoro Sub-County,

indicated that majority of the drinking water sources were contaminated. The high concentrations of TVCC and TC were an indication of a load of contamination in water otherwise meant for drinking purposes. A similar study on microbial analysis of stored and treated drinking water in Nakuru North Sub-County found that 35% (189/540) of all the samples were positive for TC (51.8%), E. coli (32.3%) and Salmonella (15.9%) respectively [13]. This indicated that the water from sources and storage household containers in Nakuru North-Sub-County did not meet the microbial quality guidelines by WHO in order to qualify for drinking purposes.

The decrease in TVCC, TC and FC levels in some household storage containers as compared to sources was probably due to the employment of treatment methods such as boiling and chlorination. An increase in the bacterial counts at households as compared to the water sources might be linked to further deterioration of drinking water with fecally contaminated hands or objects. A study conducted in Vietnam also found off-premises piped sources to contain more fecal contamination than on-premises piped sources, with evidence of similarly stored water quality for both source types [14]. Additionally, there is a possibility of contamination of water by vendors or during transportation from off premises to homesteads, during storage and handling [10].

5. Conclusion

The presence of TVCC, TC and FC in drinking water is of great public health significance and may lead to the onset of various enteric diseases. Being a fecal-oral pathogen, there are other vehicles necessary for its transmission for instance contaminated hands, foods, and utensils. The untreated water sources and household stored water used for drinking and other domestic purposes could harbor other microbes which are potential threats to the health of residents. This calls for urgent intervention strategies by the government, the community and other stakeholders to minimize the health risks associated with consumption of contaminated water.

Competing Interest

The authors have no competing of interest.

References

[1] McFeters, G. A. (2013). Drinking water microbiology: progress and recent developments. *Springer Science and Business Media, pp.* 4-6.

Appendix

Appendix 1: The WHO microbial quality guidelines for drinking water.

parameter	Guideline
Total coliforms	0 CFU/100mL
Fecal coliforms	0 CFU/100mL
Total viable cell counts	Not specified

[2] Chowdhury, S. (2012). Heterotrophic bacteria in drinking water distribution system: a review. *Environmental monitoring and assessment*, *184*(10), 6087-6137.

[3] Walter, S. (2009). *Characterization of heterotrophic plate count (HPC) bacteria from biofilm and bulk water samples from the Potchefstroom drinking water distribution system/by S. Walter* (Doctoral dissertation, North-West University), pp. 2-4. [4] An, Y. J., Kampbell, D. H., and Breidenbach, G. P. (2002). Escherichia coli and total coliforms in water and sediments at lake marinas. *Environmental Pollution*, *120*(3), 771-778. [5] Muhammad, N., Sinha, R., Krishnan, E. R., and Patterson, C. L. (2009). Ceramic filter for small system drinking water treatment: Evaluation of membrane pore Size and importance of integrity monitoring. *Journal of Environmental Engineering*, *135*(11), 1181-1191.

[6] Casanovas-Massana, A., and Blanch, A. R. (2013). Determination of fecal contamination origin in reclaimed water open-air ponds using biochemical fingerprinting of enterococci and fecal coliforms. *Environmental Science and Pollution Research*, *20*(5), 3003-3010.

[7] Djuikom, E., Njine, T., Nola, M., Sikati, V., and Jugnia, L. B. (2006). Microbiological water quality of the Mfoundi River watershed at Yaoundé, Cameroon, as inferred from indicator bacteria of fecal contamination. *Environmental Monitoring and Assessment*, *122*(1-3), 171-183.

[8] Brennan, F. P., Grant, J., Botting, C. H., O'Flaherty, V., Richards, K. G., and Abram, F. (2013). Insights into the low-temperature adaptation and nutritional flexibility of a soil-persistent Escherichia coli. *FEMS Microbiology Ecology*, *84*(1), 75-85. [9] Kiruki, S., Limo M, Njagi, M, and Okemo, P., (2011). Bacteriological quality and diarrhoeagenic pathogens in River Njoro and Nakuru Municipal water, Kenya. *International Journal for Biotechnology and Molecular Biology Research, 2* (9), 150-162. [10] Macharia, P. W., Yillia, P. T., Muia, W. A., Byamukama, D., and Kreuzinger, N. (2015). Microbial quality of domestic water: following the contamination chain in a rural township in Kenya. *Journal of Water Sanitation and Hygiene for Development*, *5*(1), 39-49.

[11] Mavura, J. W., Nyangeri, E., Nyanchaga, and Tiffani B., (2003). Fluoride contamination in Drinking water in the Rift Valley, Kenya and evaluation of a locally manufactured defluoridation Filter. *Journal of Civil Engineering, JKUAT*, *8*, 79-88. [12] Omondi, D. O., Wairimu, M. A., Aketch, W. L., William, S. A., Trick, C. G., & Creed, I. F. (2015). Faecal pollution and solar purification of community water sources within Lake Naivasha basin, Kenya. *Journal of Water Sanitation and Hygiene for Development*, *5*(2), 252-260.

[13] Nyamache, A. K., Maingi, J. M., and Waithaka, P. N. (2014). Physical-chemical and microbiological analysis in treated, stored and drinking water in Nakuru north, Kenya. *International Journal of Microbiology and Epidemiological Research, 2*(4), 29-37.

[14] Chemuliti, J. K., Gathua, P. B., Kyule, M. M., and Njeruh, F. M. (2002). Bacteriological qualities of indoor and out-door drinking water in kabera sub-location of Nairobi, Kenya. *East African Medical Journal*, *79*(5), 271-273.

[15] Brown J, Hien VT, McMahan L, Jenkins MW, Thie L, Liang K, Printy E, and Sobsey MD, (2013). Relative benefits of on-plot water supply over other 'improved' sources in rural Vietnam, *Open Journal of Medical and International Health,* 18, 65-74. [16] Nakuru Provincial General Hospital, (2009). Nakuru provincial general hospital annual laboratory report. Ministry of Health, Government of Kenya, Nakuru, Kenya.