Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Refill Stations in Selected Estates in Nairobi County

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A research project submitted to the University of Nairobi in partial fulfillment of the requirement for the award of a Master of Science degree in Tropical and Infectious Diseases

DECLARATION

This is my original work, and to the best of my knowledge, it has not been presented anywhere else.

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LIST OF ACRONYMS

ANOVA – Analysis of Variance

KNH – Kenyatta National Hospital

KRA – Kenya Revenue Authority

SPSS – Statistical Package for the Social Sciences

UNITID – University of Nairobi Institute of Tropical and Infectious Diseases

WHO – World Health Organization

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ABSTRACT

Background

Safe, adequate and accessible water is crucial in human and animal lives. If the quality of drinking-water is not checked, there could be a major burden on the health of people as a result of contamination. One way through which drinking-water can become unsafe for consumption is through microbial contamination. These microbes may include but not limited to protozoa, fungi and bacteria such as total coliforms, fecal coliforms and heterotrophic bacteria. The main objective of this study was to determine the microbiological quality of drinking water from water refill stations in selected estates in Nairobi.

Methodology

An experimental cross-sectional study design was used. Samples of water (250ml per refill station) were collected into sterile containers. Water sold in 73 refill stations in15 major estates in Nairobi County was sampled and transported to the National Public Health Water Laboratory. The water samples were tested for the presence of total coliforms, *E.coli* and fecal enterococci to check for microbial contamination. The membrane filtration method was used to enumerate the total coliforms, *E.coli* and fecal enterococci per 100ml of the water. Data was collected and entered into Microsoft excel and then transferred to the Statistical Package for Social Sciences (SPSS) software version 20 for analysis. Descriptive analysis was used for analysis of categorical variables by utilizing frequencies/proportions.

Results

The estates included in the study had varying numbers of drinking water refill stations (DWRS). Eastleigh had the highest number while several Estates such as Lavington and Kileleshwa had a few DWRS. Most of the DWRS treated tap water (n = 50, 68.5%) or borehole water (n = 22, 30.1%) to produce the drinking water. Most of them reported that they followed standard operating procedures of running DWRS, had infrastructural integrity, and maintained their facilities as

stipulated by the Water Services Regulatory Board and the World Health Organization. Microbial contamination was detected in 26 (35.6%) of the DWRS as indicated by detection of one or more coliforms per 100 milliliters.

Discussion

The quality of water sold in DWRS is generally acceptable but microbial contamination may compromise the quality. The contamination may be at the source, in the pipeline, or in the storage. Although the DWRS reported as being adherent to establishment and maintenance requirements, it is essential for regulatory authorities to ascertain the compliance since more than a third of them were selling contaminated water as safe quality drinking water.

Conclusion

Drinking water refill stations are rapidly meeting the need for quality drinking water in middle-low-income Estates in Nairobi. Owners of the refill stations self-reported compliance to requirements for running the DWRS. The detection of coliforms in more than a third of the samples indicates microbial contamination of the water.

Recommendations

Further studies are recommended for comprehensive assessment of the drinking water refill stations to identify their actual weaknesses in complying with the requirements for water quality. They should collect data through direct observation rather than relying on self-reporting. Assessment of the chemical quality of the drinking water in the DWRSs is also crucial.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

Water is an essential resource for human survival. Availability of safe drinking water is necessary for health promotion and prevention of diseases. Intra-urban inequalities in access to quality drinking water exist in Nairobi. Low-income, older, and densely populated neighborhoods are less likely to have adequate water supply (Mutono *et al.*, 2022). Residents of low-income estates experiencing water shortages may break into piped water systems in efforts to get water, which creates entry points for water contaminants. Contamination of drinking water increases the risk of diseases such as cholera, typhoid, amoebiasis, giardiasis, salmonellosis, bacillary dysentery, and infectious hepatitis, among others (Bain et al., 2014; Pal et al., 2018). Close to 10% of the global burden of disease is reportedly due to unsafe water, poor hygiene, and inadequate sanitation (Pal et al., 2018). By 2017, 785 million people in the world did not have access to safe drinking water (WHO, 2019).

The availability of quality drinking water in city Estates is dependent on the management of water from the source to distribution to the households where residents drink it. The management of drinking water supply in Nairobi estates is not structured since suppliers vary from Nairobi City Water and Sewerage Company (NCWSC) to individuals selling water in jerry cans(Nyakundi *et al.*, 2021). Water rationing by NCWSC make private suppliers of water in Nairobi key players in the provision of drinking water. Water kiosks buy water from NCWSC and retail it to consumers in the neighborhoods. Some of the kiosks have specialized in supplying quality drinking water by registering as drinking water refill stations (DWRS). The safety of drinking water is Nairobi estates is dependent on the strategies that the various water suppliers including DWRSs apply in sourcing, storing, and treating drinking water (Robinson et al., 2022).

The quality or change of quality of water is measured by use of various physicochemical assays (WHO, 2004). The non-microbial assays are used to provide early warning through detection of unusual events in the water thereby proving an avenue to take necessary steps for proper water treatment in the event of poor quality of drinking water. Some of the non-microbial parameters include colour, pH, solids, turbidity, disinfectant residual concentration and organic matter (Osuntogun & Aboaba, 2004; WHO, 2004).

Presence of colour in drinking water may indicate presence of coloured organic matter for example, highly coloured industrial wastes, humic substances or metals such as manganese (WHO, 2004). Water treatment processes such as coagulation and the disinfection with chemicals that are chlorine-based can be affected by water pH (WHO, 2004). Therefore, the pH of water needs to be monitored beginning from the source of water. Solid particles are always present in water, solids present in water can therefore range from colloidal inorganic or organic matter which never settles to debris of all sizes that can settle. These are some of both physical and chemical contaminants that can be found present in water.

There are various chemical evaluation and bacteriological enumeration techniques that are used to measure the quality of drinking water. In physicochemical analysis, parameters like toxic metals such as lead and chromium present in water can be detected using spectrophotometer (Osuntogun & Aboaba, 2004). Total dissolved solids are evaluated using gravimetric method while alkalinity, magnesium and chloride are evaluated using titrimetric method. Electronic pH meter is used for pH measurement and spectrophotometry for other chemical parameters such as potassium and sodium (Samadi et al., 2009).

Enumeration of bacteria found in water enables researchers to assess the quality of drinking water(Some *et al.*, 2021). There are various techniques that are used to carry out this exercise (World Health Organization, 2017). Membrane filter technique is a procedure which is approved in many countries for quality test for drinking water. Other techniques such as the multiple tube technique are also applied. E. coli, which is an intestinal excremental organism, is detected in both tests since it population is huge and it is easier to detect (Some *et al.*, 2021).

World Health Organization (WHO) through the International Network to Promote Safe Household Water Treatment and Storage has been committed to achieve reduction in waterborne disease by a significant number (Clasen & Mintz, 2004). In 2022, the WHO published a stepwise sanitation safety planning (SSP) document that is expected to revolutionize the drinking water supply chain at all levels including catchment, treatment, distribution, and user levels. Among its recommendation is the assessment of primary pathways to identify exposures to contamination and quantify the level of contamination (WHO, 2022). In order to achieve the goal of reducing water borne diseases, the network established by WHO is focused on promoting safe water treatment at the household level as well as proper water storage. The principles are anchored on promoting the establishment of evidence base for technologies that are household-based, advocating for water quality measures that are household-based and promotion of project implementation which includes sanitation, water and hygiene through an integrated approach, among other principles (Clasen & Mintz, 2004). The network has focused particularly on those people who are most affected by waterborne diseases, including, the poor, children, internally displaced persons as well as the refugees. Additionally, WHO emphasizes the application of microbial water quality by testing for the presence of indicators of contamination such as *Escherichia coli* in drinking water supplies (WHO, 2022). The detection of E. coli in drinking water coupled with risky sanitary conditions indicates a high likelihood of fecal contamination of the water(Nowicki *et al.*, 2021), thus posing health risks to the people drinking the water.

In order to detect the faecal indicator bacteria in water, the sanitary engineers for water utilize rapid and simple methods of testing (Ashbolt et al., 2001). However, more often these methods are broader and also less fecal-specific. For example, *Enterobacter* and several *Escherichia* spp. among others are not specific indicators of fecal contamination Therefore, this gives room for some of cases of fecal contamination to go undetected, hence resulting in unsafe drinking water. The detection of E. coli should be tested both at the point of source and point of use because of the risks of contamination in the supplying chain such as via leaking pipes and poor storage conditions. (Nowicki *et al.* (2021) observed that water at the point of use has more indicators of fecal contamination compared to water at the point of source, which implies entry and growth of potentially pathogenic microbes due to problems in the supply and storage systems.

Additionally, in countries and regions where water provided by the municipal government is reported to be unsafe, people tend to believe that bottled water is of high quality and thus safer for consumption. This factor has led to an increase in demand for bottled water over the years and this has been the case even for the developed countries such as the United States (Gardner, 2004; Napier & Kodner, 2008). It could be misleading to assume that bottled water is pure (Alwakeel & Abed, 2007). The shift in demand for bottled drinking water may pose a significant challenge to public health as more entrepreneurs who might not meet the criteria for production of safe drinking water seek to fill this demand gap (Brei, 2018). Bottled water companies have rapidly proliferated in Nairobi as entrepreneurs leverage the high demand to get business. Several of the companies package the water without strictly adhering to the international and local standards meant to assure microbial and chemical quality of drinking water. Thus, some of the brands of bottled water retailed in Nairobi are contaminated (Mohamed *et al.*, 2021). Since DWRSs are assuring the similar quality to bottled water, their demand has also increased since they mainly serve low and middle income populations that prioritize safe drinking water but cannot afford the bottled water. The establishment of DWRSs is faced by similar challenges as bottled water regard compliance with standards and measures to achieve the goal of providing reliable safe and quality drinking water.

1.1 **Statement of the Problem**

Contaminated drinking water increases the risks of people getting infected with diseases that are water-borne. Water treatment processes if not followed properly can give way to consumption of contaminated drinking water. Large populations in various regions require large amounts of water for use. With the rapid increase of Nairobi’s population resulting to higher demands of water especially when it is scarce, a possibility of unregulated water supplies to be set up in order to meet the demand is high. With these factors in place, it is highly likely that cases of water-borne diseases will rise.

1.2 **Justification**

With the rapidly increasing global population, the scarcity of safe drinking water is likely to be severe (Kokkinakis et al., 2008). Nairobi's population is rapidly increasing hence it is one of the cities likely to be affected by the scarcity of safe drinking water, translating to a high demand for bottled water. Bottled water is considered improved hence it is not suspected to be contaminated. However, fecal contamination has been noted in some improved sources of drinking water (Ashbolt et al., 2001). Mohamed *et al.* (2021) detected fecal contamination in both KRA-approved and unapproved bottled water brands being retailed in Nairobi. DWRSs that have gained popularity just as bottled drinking water could also be containing contaminants. It is therefore critical that we assess the quality drinking water sold to the public in order to guarantee its safety for human consumption and in the process prevent diseases that may be as a result of drinking contaminated water. We will obtain the total viable counts of the microbiological contaminants in the water sold at DWRS to determine the microbial safety of the water. If present, total coliforms, fecal coliforms and fecal streptococci will be identified and enumerated. The microbiological quality of the water will be established based on the counts of the bacterial contaminants in the water relative to WHO's standards (Obiri-Danso et al., 2003). The research will inform the revision of water quality guidelines to improve the decontamination and packaging standards in order to reduce microbiological contamination of water (Obiri-Danso et al., 2003;World Health Organization, 2017). It will also provide the basis for continuous microbiological monitoring of drinking water especially in those sold by water refill stations in majority of the estates in Nairobi County. The revised guidelines will contribute to the prevention of infections associated with drinking water.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Water-borne diseases are a significant health concern in Kenya and other developing countries due to challenges in the availability of safe and quality drinking water. Deficient water supply and storage infrastructure and poor hygiene are increasing the risk of spread of water-borne diseases (Some *et al.*, 2021). For instance, contaminated drinking water and recreational water accounts for many cryptosporidiosis outbreaks (Frost et al., 2005) and other diarrhoeal diseases such as cholera (Hrudey et al., 2006). Due to health concerns revolving around water quality and safety, many industries and water companies have come up with packaging techniques including bottling of drinking water for sale to the general public especially those in urban areas (Mbagaya & Mbato, 2012;Mohamed *et al.*, 2021). However, concerns on whether some of these water companies meet the required quality water standards have been raised (Kayser et al., 2015). Pathogens have been found present in some brands of bottled water (Svagzdiene et al., 2010a;Mohamed *et al.*, 2021).

The urban migration and rapid growth of population in these urban areas has also led to an increased demand for water especially in the developing countries and have over-stretched the water distribution system that is already aged or poorly maintained (Lee & Schwab, 2005;Mutono *et al.*, 2022). This phenomenon has led to people developing a perception that bottled water is of high-quality standard, potentially healthy and therefore safe for drinking. For instance, in Kenya, a majority (87.5%) of those who visit major supermarkets consume bottled water (Mbagaya & Mbato, 2012). The most common bottled water brands consumed in Nairobi are Aquamist, Dasani, Kilimanjaro and Keringet (Mbagaya & Mbato, 2012). On the other hand, there are several water refill stations that also prepare, package, refill and sell drinking water to Nairobi residents. Considering that they also package the drinking water they dispense in bottles, they are leveraging on the high demand for bottled water to meet the drinking water needs of people who cannot regularly afford bottled water (Yusnita *et al.*, 2020).

2.1 Common microbial water contaminants

Pollution of water through fecal contamination exposes the water to pathogens with a potential to cause disease outbreaks. The possible pathogens include *Vibrio cholera*, *Salmonella typhi*, Shigella spp. that cause cholera, typhoid and paratyphoid, and Shigellosis respectively. Others are various pathogenic forms of *E. coli* including enterohemorrhagic, enteropathogenic, enterotoxigenic, enteroinvasive, and enteroaggregative *E. coli* that cause diverse types of diarrhea (Some *et al.*, 2021). To prevent and protect the public from health crisis that could arise from outbreaks of water-borne diseases caused by the pathogens, proper measures to detect fecal contamination by testing for coliform bacteria are put in place. To check for sanitary quality of water and food, coliform bacteria are the commonly used indicator for bacterial presence in the water or food since they are abundant in human and animal feces (World Health Organization, 2017). Enterococci and *Escherichia coli* are some of the coliforms that indicate water contamination especially with human fecal matter (Staradumskytė & Paulauskas, 2012). Other detectable microbial contaminants include environmental coliforms which comprise bacteria found in surface water, soil and in wastes from animals or humans. Fecal coliforms fall under total coliforms with an exception that they are considered to be present in the warm-blooded animals' feces and gut (Staradumskytė & Paulauskas, 2012).

2.2 Regulations and standards on safe drinking water

Clean and safe water for consumption should meet the WHO water quality standards (Organization, 2011) as well as the Kenyan water quality standards in order to be approved for use in the country. The WHO stipulates that governments should come up with national drinking-water standards and programs that are based on clear policies that are consistent with the international goal of provision of clean and safe water for consumption (World Health Organization, 2017) . In general, *Escherichia coli* or thermotolerant coliform bacteria must not be detected in any 100 ml sample of water intended for drinking, treated water entering the distribution system or treated water in the distribution system (World Health Organization, 2008).

The government of Kenya through KEBS has laid down legal frameworks through which drinking water companies and vendors must follow to ensure safe drinking water reach the public. These water entities must comply with water standards such as quality source of water, code of hygiene and proper labelling. The Water Services Regulatory Board (WASREB) has developed a guideline to guide the standardization of drinking water for quality in Kenya by detailing steps and considerations when monitoring water for chemical and microbiological quality. It specifies microbiological limits for various types of drinking water in compliance with the Water Act of 2016 (WASREB, n.d.). Additionally, other requirements for operation of water kiosks as per KEBS include automation of bottle filling and sealing and undergoing quality assurance audit regularly. Proper waste management, maintenance of equipment and water plants, continuous monitoring and hygiene of water and proper handling and packaging of containers have been emphasized by WHO.

Researchers have explored the microbiological quality of drinking water sold in some cities and towns in various countries globally. In their study, Lau and Page found about 17 out of 38 domestic and imported bottled water brands in New Zealand as having at least one indicator of fecal contamination (Svagzdiene et al., 2010b). In another study that determined the difference in quality of water, Da Silva et al. compared the microbiological quality of bottled drinking water and the water from the municipal water systems in Maringa´ City in Brazil and found bottled water in dispensers to have more contaminants than municipal tap water (Zamberlan da Silva et al., 2008).

Obiri-Danso et al. investigated the microbiological quality of bottled drinking water sold along the streets of Kumasi in Ghana (Obiri-Danso et al., 2003). None of the indicators of fecal contamination, total coliforms, fecal coliforms, or fecal streptococci were detected in the bottled water. However, in another study done in Tanzania, heterotrophic bacteria were found in 92% of the samples of bottled water that was tested (Kassenga, 2007). It was found that both fecal coliforms (in 3.6% of the samples) and total coliform bacteria (4.6% of the tested samples) were present and the rates of water contamination were found to be higher for drinking water packaged in plastic bags when compared to bottled drinking water. Different factors including but not limited to difference in water quality regulations and water testing procedures could be responsible for the differences in presence of microbial water contaminants between the two countries.

In a different study done in Kenya, even with various brands of bottled water being approved, bacteria were still found to be present in some bottled drinking water. Mohamed et al. found 16% of Kenya Revenue Authority (KRA)-approved and 35.3% of banned brands of bottled drinking water retailing in Nairobi to be contaminated with heterotrophic bacteria (Mohamed et al., 2020). About 4% and 17% of the approved and banned brands respectively had fecal coliforms (Mohamed et al., 2020).

2.3 Tests for bacteriological enumeration

. Membrane filter technique that is used to test the bacteriological quality of water involves filtering of water sample through a 0.45 µm pore size sterile filter that block bacteria from passing through. The filter paper is then incubated in selective medium and typical colonies are enumerated on the filter (Rompré et al., n.d.). Multiple-tube fermentation technique is another method that is used to enumerate coliforms to monitor water quality and the results from this method are illustrated in terms of an estimate of mean number of coliforms present in the water sample (Rompré et al., n.d.). Other methods include plate count where the bacteria obtained from the drinking water is grown on a nutrient agar and the colonies are visible to the naked eye and therefore can be counted (Reasoner, 2004). To achieve reliable results with this technique, various serial dilutions have to be made.

2.4 Main Objective

To determine the microbiological quality of drinking water from water refill stations in selected estates in Nairobi County.

2.5 Specific Objectives

1. To detect indicators and enumerate the fecal coliforms in drinking water from water refill stations in Nairobi County.

2. To evaluate bacterial level and quality of processed water in compliance to the WHO drinking water standards.

3**.** To assess the quality of the water refill stations in providing safe drinking water.

CHAPTER THREE: METHODOLOGY

3.1 Study design

Experimental cross-sectional study design was used.

3.2 Study site

Water samples were collected from water refill stations found in Embakasi, Langata, South B, South C, Nairobi West, Madaraka, Eastleigh, Buruburu, Imara daima, Donholm, Umoja,Kilimani, Lavington and Kileleshwa estates in Nairobi County. These estates were selected because they have many water refill stations which serve a lot of people. Secondly, most middle income families that cannot afford bottled water regularly but consider it the drinking water of choice live in the selected Estates, hence DWRSs are located there to target them.

3.3 Sampling technique

We used convenience sampling technique while considering coverage of the estates and frequency of water refill stations in each estate to select the water refill stations to include in the study. The water refill stations were selected based on their readiness to provide water samples for testing and respond to the survey questions until the required sample size was attained.

3.4. Variables

3.4.1 Independent variables

- Source of water
- Water handling hygiene
- Water treatment procedures
- Bacterial count per unit volume of water
- Type of bacteria present in water

3.4.2 Dependent variables

- Safety and the quality of water

3.5 Sample size determination

To determine the sample size for the study, we used Fisher's formula.

Sample size (n) = $\frac{Z^2 P(1-P)}{C^2}$

Where; Z (Confidence level) = 1.96

P (Estimated prevalence) = 95% based on most studies done in developing countries

C (Confidence interval) = 0.05

Therefore; n = $\frac{1.96^2 X 0.95(1-0.95)}{0.05^2}$ thus, 73 water samples were collected from water vendors.

3.6 Sample collection

Samples of water were collected from major estates with larger population in Nairobi where73 water refill stations were randomly selected.

After fully explaining the purpose of the study to the water refill stations' operators, the operators proceeded to sign a written consent form and supplied with a questionnaire which they filled. The questionnaire designed to collect data on source of water, water treatment procedures, handling, transportation and general maintenance of water hygiene. The water vendors were also asked for permission for the researcher to collect water samples for microbial testing and water quality assessment.

3.7 Microbiological analysis and water quality assessment

Water samples measuring 250 ml each were collected in a sterile container from each of these water refill stations. The samples of water were transported to the National Public Health Water Laboratory with in six hours. A predetermined amount of sample (100ml) was filtered through a membrane filter that retained the bacteria found in the sample shown in figures 1 and 2. The filters containing bacteria were placed on a chromogenic agar and incubated at 40^0C for 22 hours. Colonies were eliminated according to the colour they formed (coliforms were pink and *E. coli* was blue in colour). Colonies were then counted under magnification and reported per 100 mL of original sample. Another 100ml was filtered through a membrane filter and the filters containing the filtrates were placed on the surface of Bile esculin agar for enterococcus. (Enterococcus species formed black colonies).

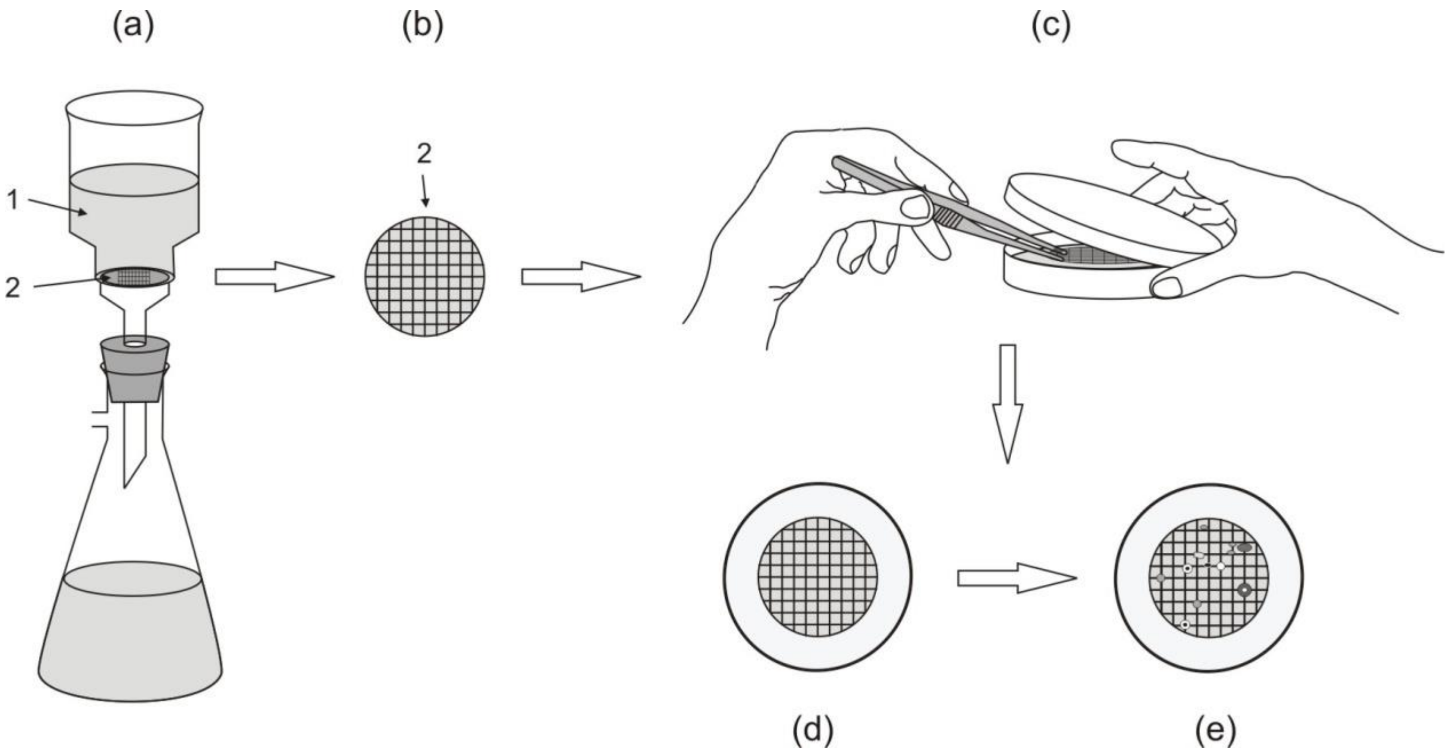

Figure 1: Method of membrane filtration

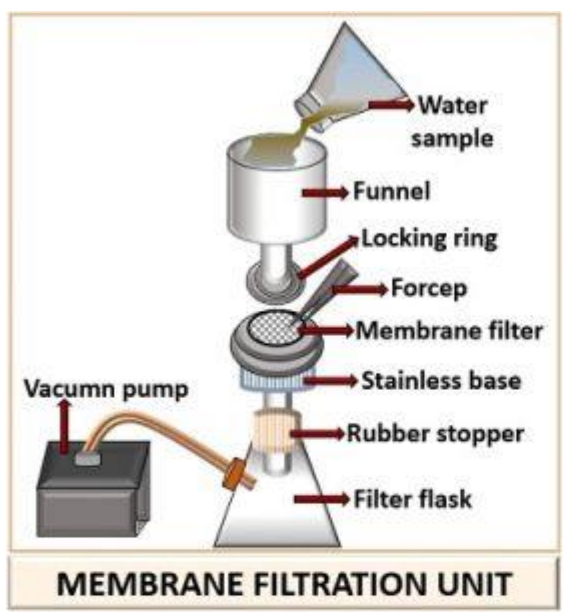

Figure 2: Parts of a membrane filter

3.8 Quality assurance

We pre-tested the questionnaire before administering it to the study participants and made appropriate changes.

Data cleaning was done at the end of each day when data collection was done.

3.10 Data management

The generated data was entered into Microsoft excel. We used SPSS Statistics software version 20 to analyze data imported from Microsoft excel.

Descriptive analysis was used for analysis of categorical variables by utilizing frequencies/proportions. We used Chi-square to test if the frequency distribution of categorical variable was different from our expectations.

3.11 Study result dissemination

The results from this study were presented to the University of Nairobi, Department of Medical Microbiology. We will also share our findings with the County government of Nairobi's ministry of water and sanitation to aid in policy-making.

3.12 Ethical considerations

We submitted our protocol to KNH – UoN Ethics and Research Committee to seek for approval to conduct the study. Once we got the approval (P984/12/2021), we applied for a license at the National Commission for Science, Technology & Innovation (NACOSTI). When we got the license (NACOSTI/P/22/19020), an informed consent covering the study aspects was prepared and presented to each and every participant who took part in the study to sign. The collected data were stored in computers that were password-protected in order to ensure safety of the data.

CHAPTER FOUR: RESULTS

4.1 Water refill stations sampled per site

As shown in **Table 1**, almost a quarter (n= 18, 24.7%) of the drinking water facilities sampled were in Eastleigh. Only one refill station from each of Kileleshwa, Lavington, and Madaraka was included in the study. Langata (n=3), Kilimani (n=3), Umoja (n=3) and Nairobi west (n=4) are additional locations with few refill stations. According to **Table 1**, the number of refill stations in the other six locations ranged from six to eight.

Table 1: The number of water refill stations sampled per site

Location	**Refill stations sampled (n=73)**	**Percentage**
South B	7	9.6
South C	6	8.2
Donholm	8	11
Umoja	3	4.1
Buruburu	6	8.2
ImaraDaima	6	8.2
Emabakasi	6	8.2
Eastleigh	18	24.7
Langata	3	4.1
Kileleshwa	1	1.4
Kilimani	3	4.1
Lavington	1	1.4
Nairobi west	4	5.5
Madaraka	1	1.4

4.2 Conditions of the water refill stations

The main water sources for the refill stations were tap water (n = 50, 68.5%,) and borehole (n = 22, 30.1%). Only one refill station got water from surface water while none relied upon spring water as shown in **Table 2.** Most of the refill stations had the documentation needed to supply refill water. Standard operating procedures were reported as available in 52 (71.2%) of the refill stations as indicated in table 2. Certificates of good hygiene and sanitation were owned by all the 73 refill stations. Regarding infrastructural integrity, all the 73 refill stations had well maintained water storage and distribution systems to prevent water contamination. In addition, they all had well designed water vending facilities for easy and hygienic use and maintenance. The drainage systems for wastewater were also well maintained in all the 73 the facilities.

Table 2: Assessment of the conditions of the drinking water refill stations

Parameter	Response	Count (Percentage)
Source of water	Spring water	0 (0)
	Bore hole	22(30.1)
	Well	0(0)
	Tap water	50(68.5)
	Surface water (Lake, Dam/Water Reservoir)	1(1.4)
Availability of Standardized operating procedures	Yes	52 (71.2)
	No	21 (28.8)
Own certificate of good hygiene and sanitation	Yes	73(100)
	No	0(0)
Water storage and distribution systems well maintained	Yes	73 (100)
	No	0(0)
Staff trained on hygiene and sanitation	Yes	66 (90.4)
	No	7(9.6)
Run out of drinking water supply	Very often	0 (0)
	Often	1 (1.4)
	Sometimes	39 (53.4)
	Rarely	23(31.5)
	Never	10 (13.7)
Facility design for easy and hygienic use and maintenance	Yes	73(100)
	No	0(0)
Toilets location	In separate blocks	71 (97.3)
	Same block as the facility	2(2.7)
Regular inspections and control of flies and other insects	Yes	73 (100)
	No	0 (0)
Availability of handwashing facilities	Yes	73 (100)
	No	0 (0)
Well-designed drainage system	Yes	72 (98.6)
	No	1 (1.4)
Drainage system well maintained	Yes	73 (100)
	No	0 (0)

The toilets used by the staff of 71 (97.3%) of the 73 refill situations are located in separate blocks while the remaining two have toilets in the same block as the drinking water facility. Therefore, the toilets of most of the drinking water facilities are located at the right place. Additionally, all the refill stations have handwashing sinks.

Regarding training on effective methods of providing water hygiene, 66 (90.4%) of the refill stations had their owners or their staff trained. Hygiene is further enhanced through regular inspections and control of flies and other insects in all the 73 facilities.

Slightly more than half (39, 53.4%) of the drinking water refill stations sometimes ran out of drinking water supply. Another 31.5% rarely experiences supply challenges. Only 10 (13.7%) have never ran out of drinking water supply. Notably, the issue of drinking water supply is not a major problem since only one refill station indicated as running out of drinking water often and none experienced the challenge very often as indicated in **Table 2.**

4.3 Microbiological analysis of the water sampled from the refill stations.

Analysis of the water samples for contamination with coliforms and *E. coli* showed that 26 (35.6%) of the refill stations had unsatisfactory counts of colony forming units (CFU) per 100ml. The drinking water is treated hence satisfactory results are marked by absence of coliforms, *E. coli*, and all other tested bacteria. Notably, a sample from one station had more than 10000 CFU/100ml; all the other samples with unsatisfactory results for coliforms had 1-100 CFU/ml. With the exception of two stations, one in Donholm and the other in Buruburu, all of the samples from the water refill stations were contaminated with Enterococcus species 71 (97.3%).

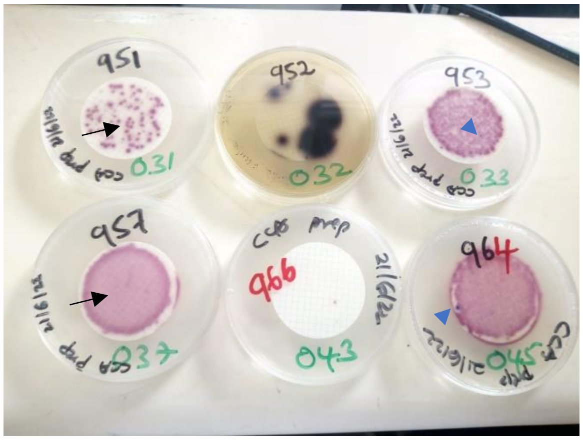

Figure 3: Colonies of coliforms (pink, pointed at by black arrows) and *E. coli* (blue, pointed at by blue arrow heads) as obtained when filter papers used on water samples inoculated on chromogenic agar and incubated at 40^{0}C for 22 hours

Drinking water refill stations whose samples had unsatisfactory counts of coliforms were in 9 of the 14 estates as shown in **Table 3**. In five out of the 14 estates, more than 50% of the water refill stations had coliforms in the water. Coliforms were not found in any of the DWRSs sampled in Umoja, Langata, Kilimani, Lavington, and Madaraka. In Eastleigh, 8 (44.4%) of the18 DWRSs sampled were contaminated with coliforms *E. coli*. Two of the eight DWRS with unsatisfactory results in Eastleigh not only had coliforms but also *E. coli.* High rates of contamination were also recorded in South C where all the three sampled DWRSs (100%) were contaminated. Coliforms were detected from the only DWRS in Kileleshwa included in the study.

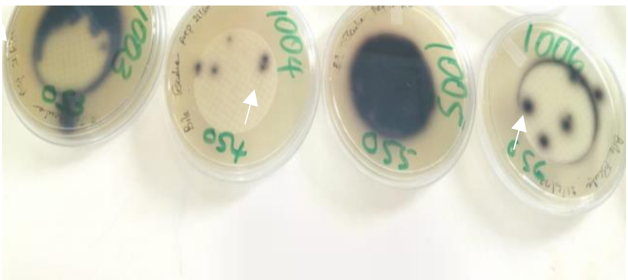

Figure 4: Colonies of enterococcus species (black, pointed at with white arrows) as obtained when filter papers used on water samples 53, 54, 55 and 56 were inoculated on bile esculin agar at 40^{0}C for 22 hours.

Table 3: Number and proportions of stations with unsatisfactory coliforms and *E. coli* counts

Location	**Frequency (n=73)**	**Number of Stations with coliform counts/100ml**	**Number of Stations with *E. coli* counts / 100 mL**	**Percentage of stations with unsatisfactory counts**
South B	7	1	0	14.3
South C	6	3	0	50
Donholm	8	3	0	37.5
Umoja	3	0	0	0
Buruburu	6	2	0	33.3
ImaraDaima	6	3	0	50.0
Emabakasi	6	3	0	50.0
Eastleigh	18	8	2	44.4
Langata	3	0	0	0.0
Kileleshwa	1	1	0	100.0
Kilimani	3	0	0	0.0
Lavington	1	0	0	0.0
Nairobi west	4	2	0	50.0
Madaraka	1	0	0	0.0
%Unsatisfactory		35.6%	2.7%	

4.4 Indicators of Quality and the Microbiological Quality of Water

Although chi-square tests of the associations between the indicators of quality and the microbiological quality of water did not reveal any significant associations, notable differences in rates of contamination among DWRSs that reported diverse features were observed. Out of the 26 DWRSs whose water samples were contaminated with coliforms, the 22 that used borehole as a source of water for purification had a higher rate of contamination (n = 10, 45.5%) compared to the 50 that used tap water as their source (n = 16, 32%) as shown in **Table 4**. A higher proportion of the DWRSs that indicated to have SOPs had contaminated water (n = 20, 38.5%) compared to the ones that reported not having them (n = 6, 28.6%). The rate of contamination was higher in DWRSs that reported to have not trained on effective methods of providing water hygiene (n = 3, 42.9%) compared to the ones that reported training (n = 23, 34.8%).

Table 4: Chi associations between variables

Parameter	Response	Percentage	Enterococcus		Coliform/ *E. coli*	
			Present (%)	P-value	Present (%)	P-value
Source of water	Spring water	0 (0%)	0 (0%)		0 (0%)	0.41
	Bore hole	22(30.1%)	22 (100%)		10 (45.5%)	
	Well	0(0%)	0 (0%)	0.49	0 (0%)	
	Tap water	50(68.5%)	48 (96%)		16 (32%)	
	Surface water (Lake, Dam/Water Reservoir)	1(1.4%)	1 (100%)		0 (0%)	
Availability of Standardized operating procedures	Yes	52 (71.2%)	50 (96.2%)		20 (38.5%)	0.3
	No	21 (28.8%)	21 (100%)	0.36	6 (28.6%)	
Own certificate of good hygiene and sanitation	Yes	73(100%)	71 (97.3%)		26 (35.6%)	0.73
	No	0(0%)	0 (0%)	0.73	0 (0%)	
Water storage and distribution systems well maintained	Yes	73 (100%)	71 (97.3%)		26 (35.6%)	0.73
	No	0(0%)	0 (0%)	0.73	0 (0%)	
Staff trained on hygiene and sanitation	Yes	66 (90.4%)	64 (97%)		23 (34.8%)	0.48
	No	7(9.6%)	7 (100%)	0.74		
Run out of drinking water supply	Very often	0 (0%)	0 (0%)		0 (0%)	0.4
	Often	1 (1.4%)	1 (100%)		1 (100%)	
	Sometimes	39 (53.4%)	38 (97.4%)	0.9	15 (13.9%)	
	Rarely	23(31.5%)	22 (95.7%)		6 (26.1%)	
	Never	10 (13.7%)	10 (100%)	0.73	4 (40%)	
Facility design for easy and hygienic use and maintenance	Yes	73(100%)	71 (97.3%)		26 (35.6%)	0.73
	No	0(0%)	0 (0%)	0.92	0 (0%)	
Toilets location	In separate blocks	71 (97.3%)	69 (97.2%)		25 (35.2%)	0.59
	Same block as the facility	2(2.7%)	2 (100%)	0.73	0 (0%)	
Regular inspections and control of flies and other insects	Yes	73 (100%)	71 (97.3%)		26 (35.6%)	0.73
	No	0 (0%)	0 (0%)		0 (0%)	
Availability of handwashing facilities	Yes	73 (100%)	71 (97.3%)	0.73	26 (35.6%)	0.73
	No	0 (0%)	0 (0%)		0 (0%)	
Well-designed drainage system	Yes	72 (98.6%)	70 (97.2%)		26 (36.1%)	0.64
	No	1 (1.4%)	1 (100%)	0.96	0 (0%)	
Drainage system well maintained	Yes	73 (100%)	71 (97.3%)	0.73	26 (36.1%)	0.73
	No	0 (0%)	0 (0%)		0 (0%)	

CHAPTER FIVE: DISCUSSION

Overall, fecal contamination was detected in some drinking water refill stations. Lower-income neighborhoods had more DWRSs. There was some mismatch between the self-reported compliance with guidelines and contamination state of drinking water in the DWRSs whereby high compliance rates were reported but contamination was detected.

5.1 Frequency of drinking water refill stations by neighborhoods

Low-income neighborhoods like Eastleigh had more drinking water outlets compared to high- and middle-income estates like Kileleshwa and Lavington, hence the decision to increase their representatives in the sample. Residents of high and middle-income neighborhoods are six and four times more probable than residents of low-income neighborhoods to receive a supply of tap water in the household of at least 1500 L per capita per month respectively (Mutono et al., 2022).

Since the residents of high-income neighborhoods may have equipment to purify drinking water and are sparsely populated, they could be leveraging the adequate supply of tap water in their houses to meet their drinking water needs. They could also be purchasing bottled water rather than using the services of the drinking water refill stations (Sima et al., 2012). On the other hand, the rationing of tap water, high density of population (Mutono et al., 2022), and challenges affording the water purification equipment may be prompting the high demand for drinking water sold in refill stations in low-income neighborhoods such as Eastleigh.

5.2 Sources of water for the refill stations

The results showed that the drinking water refill facilities in the Nairobi Estates rely on tap and borehole water as a source of the raw water to process. The 42 brands of bottled water in the study by Zarei and Semerjian (Mohamed et al., 2021) also obtained their water from taps (19) and boreholes (23). Both the World Health Organization (WHO) and the WASREB recognize boreholes and tap water as reliable sources of drinking water upon the required treatment (WASREB, 2008; WHO, 2017).

Running out of drinking water supply as reported in some of the refill stations is a threat to water quality. It may necessitate prolonged water storage that may complicate observance of hygienic measures, hence resulting in recontamination of treated water (Chalchisa et al., 2017). Since more than half of the refill stations only experience the shortages in water supply occasionally, they may not have mechanisms for quality assurance of water storage during the supply hitches.

5.3 Compliance to requirements

The drinking water refill stations are mainly compliant to the requirements for drinking water safety and quality. The results of the current study show that all the refill stations sampled owned certificates of good hygiene and sanitation. Certification shows that the drinking water facilities meet the level of safety and quality specified by the certification agency (World Health Organization, 2017).

The refill stations also had standard operating procedures that they follow to ascertain quality of the water. According to WHO guidelines on drinking water (World Health Organization, 2017), water treatment processes and maintenance of distribution systems should be guided by documented standard operating procedures. In addition, each of the processes preceding dispensing of water at the refill stations should be guided by a standard operating procedure. The owners of the surveyed water refill stations indicated that they train their personnel on water hygiene, which entails adhering to the standard operating procedures for operating the refill stations.

Water storage and distribution systems are integral in the provision of clean drinking water. The indication that the refill stations are properly designed and they maintain their storage and piping systems to avoid contamination shows adherence to established guidelines. For example, situating toilets used by the staff of the refill station at the right place as the owners of the surveyed refill stations indicated to have done is an infrastructural design intervention that can significantly contribute to reducing the risk of contamination. Additionally, placing hand washing stations strategically near the toilets reduces the risk of transfer of enteric pathogens from the toilet to the water refill facility.

The risk of cross-contamination of water in the distribution system and unsafe storage is often overlooked by water professionals yet it is a major source of water borne diseases (Chalchisa et al., 2017). A design that facilitates thorough cleaning and proper maintenance prevents structural faults that allow leakages, which would have served as entry points for contaminants (World Health Organization, 2017). Including a plan for controlling flies, which the owners declared as having done, is crucial in maintaining the hygiene of the facility.

5.4 Microbiological Quality of Drinking Water

The unsatisfactory results in the microbiological quality of drinking water in more than a third of the water refill stations sampled indicate that these stations are not compliant to WHO standards. The findings are consistent with the results of a previous study conducted in Umoja Innercore Estate that found 100% of borehole water and 30% of household water were microbiologically unsatisfactory due to contamination with coliforms and *E. coli* (Nyakundi et al., 2020). Another study detected *E. coli* in 63% of stored drinking water in Kibera, Nairobi (Bauza et al., 2019), which implicates the source and piping systems in the contamination of drinking water in Nairobi.

The unsuitability of the quality of drinking water in drinking water refill stations is seemingly a substantial problem in middle-low urban locations. Just as the current study, a cross-section study that examined the quality of drinking water in Bandung City in Indonesia found the quality of water dispensed in drinking water refill stations to be poor (Yusnita et al., 2020). Out of the 229 refill stations they included in the sample, they found that 37.6% had drinking water whose quality was not suitable (Yusnita et al., 2020). Since the survey in the current study regarding compliance to regulations was self-reported by owners, the results showing high levels of compliance could be due to bias. The high number of refill stations in middle-low-income estates as observed in the current study could be complicating surveillance by regulatory agencies responsible for ascertaining the quality of water in the refill stations considering that the staff allocated to cover the estates may not be able to assess all the DWRSs.

The borehole water may be getting contaminated by seepages from septic tanks. Since tap water and boreholes are the main water sources for the drinking water in the refill stations, the high rates of contamination of their water is an indication that the contamination might have occurred during processing. The vending facility whose water had more than 10000 cfu/ml may have not treated its water before presenting it for sale as processed drinking water. Water in one borehole and one household in the study by Nyakundi et al. (Nyakundi et al., 2020) also had high counts of *E. coli*, 1100 cfu/ml. In addition, the facilities whose water had 1-100 cfu/ml may have improperly treated their drinking water that they had obtained from highly contaminated sources.

5.5 Sources of microbial contamination of water

Although tap water may be treated from the source, for example by Nairobi Water Supply before distribution to households, several infrastructural challenges increase its risk of contamination in the pipeline. Estates highly likely to have such infrastructural challenges such as Eastleigh due to poor maintenance had high rates of contamination in the current study. Corroded pipes and broken pipes due to the poor maintenance of the old pipe network coupled with overflowing sewage predispose the water to contamination before it reaches the consumption point (Nyakundi et al., 2020). The drinking water facilities that rely on tap water as the source of their water for processing may treat the water by adding an amount of chlorine recommended for water treated at the source without realizing that the water may have been contaminated in the pipeline. Thus, they may treat the water inadequately, leaving contaminants in it.

The contamination in water refill stations in Nairobi transfers to bottled water since some water bottling companies rely on the DWRSs as their source of water. Zarei and Semerjian (Mohamed et al., 2021) found 35.3% of bottled water banned by Kenya Revenue Authority (KRA) and 16% of KRA-approved bottled water sold in Nairobi to be contaminated with heterotrophic bacteria. Total coliforms and fecal coliforms were present in 17%

of the banned brands and 4% of the approved brands. It could be that water is poorly processed at the refill stations since the samples in the current study and the bottled water samples in the study by Zarei and Semerjian (Mohamed et al., 2021) were substantially contaminated. According to Bauza et al. (Bauza et al., 2019), inadequate treatment of drinking water with chlorine is common as evidenced by absence of free chlorine residuals from water samples in 60% of the households that had indicated as having treated their water with liquid chlorine.

5.6 Implications of detecting enteric coliforms

The detection of *E. coli* in samples from water refill stations explains the presence of *E. coli* in bottled water sold in Nairobi. *E. coli* was the commonest bacteria in the microbiological analysis of 42 different bottled water brands in Nairobi (Mohamed et al., 2021). Presence of *E. coli* should raise the suspicion that the water is unsafe for drinking and warrant advanced treatment. The water services regulatory board (WASREB) guidelines (Water Services Regulatory Board (WASREB), n.d.) indicate that counts of enteric coliforms such as *E. coli* should be quadrupled when selecting the criteria to use during treatment of contaminated water.

E. coli contamination of water is often accompanied by other enteric pathogens. In the current study, enterococcus was detected in almost every water sample. In the study by Bauza et al. (Bauza et al., 2019), 13% (5) of the 25 drinking water samples that had *E. coli* had at least one other enteric pathogen. The more the enteric pathogens in water, the higher the risk of causing water-borne diseases among the people who drink the water.

5.7 Value of chlorination in treating water

In this study, most of the water refill stations used chlorination as the water treatment method. In the study by Zarei and Semerjian (Mohamed et al., 2021), chlorination was associated with meeting the WHO limits. Water processing systems are prone to bacterial entry and colonization if proper disinfection using evidence-based approaches such as chlorination is not done. About 43% of the households included in the study by Bauza et al. (Bauza et al., 2019) had treated the drinking water stored in their households, with most of them using liquid chlorine or tablet chlorine to treat the water (Bauza et al., 2019). In addition, no pathogens were detected in the samples from the water sources that the residents had indicated that they had treated before storage (Bauza et al., 2019).

5.8 Maintenance of drinking water refill stations

Although the water refill station owners indicated that they adhere to the standard operating procedures to ascertain the hygiene of the drinking water, the microbiological assessment revealed that there were lapses in the water systems. The high rate of contamination among the DWRS that indicate as adhering to standard operating procedures compared to the ones that did not implies that the self-reports could be misleading. Compliance to the WHO drinking water standards could be impended by the small sizes of the drinking water refill stations in most estates. A substantial water quality budget is required to adequately train staff and conduct the microbial water testing that is needed for quality assurance in supplying clean drinking water (Peletz et al., 2016). Results of operational monitoring tests such as the testing for indicator bacteria in the water at the refill stations can flag the need for corrective actions in the water supply system to ensure that the water is not contaminated (Peletz et al., 2016).

Based on the recommendations by water services regulatory board (WASREB) guidelines (Water Services Regulatory Board (WASREB), n.d.), the refill stations identified as dispensing contaminated water ought to apply diverse measures to treat their water based on the extent of contamination. For the refill facilities where only 0-50 coliforms/100ml were detected, only disinfection of the water is needed. Full treatment comprising coagulation, sedimentation, filtration, and disinfection of the source water is recommended for the refill stations that recorded 50-5000 coliforms/100 ml (Water Services Regulatory Board (WASREB), n.d.). The DWRSs sourcing water from boreholes should particularly organize for the treatment of source water since they had higher rates of contamination compared to the ones that relied on tap water. The source water used by the single refill station in Eastleigh that had 24, 000 coliforms/100 ml ought to be extensively treated since it is heavily contaminated (Water Services Regulatory Board (WASREB), n.d.).

When properly maintained, drinking water refill stations are as beneficial as bottled water in public health. The results of the current study showed that most drinking water refill stations dispense hygienic water. Besides, the rate of detection of coliforms in the refill stations almost matches the rate in bottled water (Mohamed et al., 2021). Sima et al. (Sima et al., 2012) found that the rate of diarrhea among children who drink water from refill stations matches the rate among the children who drink bottled water. The rate of diarrhea per 1000 child days was 3.60 and 3.97 for children who drank bottled water and children who drank refill stations' water, respectively. Both were significantly lower than the rate among the children who drank tap water directly, who got diarrhea at a rate of 8.13 per 1000 child-days (Sima et al., 2012). Therefore, people who cannot afford bottled water can effectively use drinking water from refill stations since it is equally beneficial in preventing diarrheal infections.

Quality assurance of drinking water sold in drinking water refill stations is a crucial need in Nairobi. The drinking water refill stations are expected to increase in estates in Nairobi since they provide a relatively affordable alternative to branded bottled drinking water. Most residents of the estates such as Eastleigh are middle-low-income earners, hence the more affordable and practical approach of refiling drinking water will continue becoming embraced. Yusnita et al. (Yusnita et al., 2020) identified Kenya as among the countries whose urban communities have features that facilitate the rapid spread of drinking water refill stations. The assertion was supported by the current study's location of refill stations in every estate visited and the high number of refill stations in some Estates such as Eastleigh. Thus, regulation of the DWRSs should be up scaled to match the rate of the establishment of DWRSs in Nairobi Estates.

5.9 Limitations of the study

The survey to assess compliance to regulations was self-reported by owners. The owners may have exaggerated their compliance to portray their refill stations as matching the expected quality standards. The scope of the survey was limited to determining the microbiological quality of water only due to the scarcity of resources for conducting the laboratory tests. Assessing the chemical composition of the water in addition to the microbiological assessment would have produced a more comprehensive analysis of the quality of the water in the refill stations.

5.10 Recommendations

WASREP should recognize DWRSs as among the safe sources of drinking water in Nairobi Estates. It should develop specific guidelines that DWRSs can apply to meet the standards for safe and quality drinking water. The prevailing high cost of living can push even people who depend on bottled drinking water to shift to DWRSs, hence it is critical to establish solid mechanisms to ensure the water they sell is safe for drinking. The KEBS and other government agencies responsible for enforcing the guidelines should do objective assessments of the DWRS to ensure they meet the specified standards since this study established that subjective assessment with owners of the DWRSs as the respondents could be generating biased data. The proposed initiatives will fast tract progress on drinking water (SDG 6.1), which is 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all' by increasing the proportion of safely managed drinking water services.

Further studies are recommended for comprehensive assessment of the drinking water refill stations to identify their actual weaknesses in complying with the requirements for water quality. They should collect data through direct observation rather than relying on self-reporting by the staff of the DWRSs. They should analyze the correlation between compliance with the various regulations and levels of contamination of water sold to determine the main sources of contamination. Water quality assessment comprising the chemical content of water is recommended to enhance the comprehensiveness of the report in informing changes in the sourcing and processing of the water vended in refill stations.

6.0 Conclusion

Drinking water refill stations (DWRS) are becoming common in Nairobi Estates. Middle-low-income Estates such as Eastleigh where majority of residents cannot afford bottled drinking water or water purification equipment are turning to the drinking water refill stations for safe drinking water. Tap water in their houses may have been contaminated from the source or during supply due to leakages in the piping system considering the contact with overflowing sewage. The findings of this study indicate that most of the owners of the DWRS reported to be mainly compliant to the requirements for establishing DWRS and maintaining them as stipulated by the WHO and the Water Services Regulatory Board. The DWRS included in the sample sourced their water mainly from the tapped water system and boreholes. Chlorination is the water treatment method used by all the DWRS. Microbial assessment of the quality of water sold in the sampled DWRS showed that a third of them dispensed water that was not meeting the microbiological standards for drinking water. Thorough surveillance of the DWRS is needed to ascertain whether they meet the requirements as reported by the owners and identify the sources of the contamination. Future research should include a chemical assessment of the quality of the water to generate a comprehensive report on the overall quality of water sold in the DWRS.

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APPENDICES

Appendix 1: Consent Form

Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Vending Kiosks in Selected Estates in Nairobi County

I would like you to participate in a research study that we are doing, the topic is **Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Vending Kiosks in Selected Estates in Nairobi County.** The researchers: Dr.**Saadia Ahmed,** Dr. **Winnie Mutai**andProf.**JuliusOyugi** will conduct the study. The purpose of this consent form is to give you the information you will need to help you decide whether or not to be a participant in the study, the possible risk and benefits, your rights as a volunteer and anything else about the research or this form that is not clear. Once you understand and agree to be in the study, we will request you to sign your name on this form.

These are the general principles that all participants in medical research should understand:

I. Your decision on participation is entirely voluntary
II. You may withdraw from the study at any time without necessarily giving a reason for your withdrawal
III. Refusal to participate in the research will not affect the services that you are entitled to offer at your water vending kiosk.

What is this study about?

We are doing the study todetermine the microbiological quality of bottled drinking water sold by vending kiosks in selected estates in Nairobi.

What will happen if you decide to be in this research study?

If you agree to participate in this study, the following things will happen;

We will ask you a few questions which will take approximately five minutes. The questions will be about source of water for the vendor, water treatment procedures, handling, transportation and general maintenance of water hygiene.

Are there any risks, harms discomforts associated with this study?

You may also feel uncomfortable when answering some of the questions. If there are any questions you do not want to answer you can skip them. You have the right to refuse any questions asked during the conduct of the study.

How will my personal information be protected?

The information we collect from you will remain confidential. This will be achieved through the use of a code number to identify you in a password protected computer database and we will keep all of our paper records in a locked file cabinet.

Are there any benefits for being in this study?

You may not directly benefit, however, the information that you provide will help us to better understand the safety of drinking water and through our recommendations, policy makers will be able to make informed policies in regards to safety of drinking water. This information is a contribution to science.

What if you have questions in the future?

If you have further questions about participating in this study, please call or send a text massage to the principal investigator: **Dr. Saadia Ahmed Guhad   Contact: +254716660949**

For more information about your rights as a research participant you may contact the Secretary/Chairperson, Kenyatta National Hospital-University of Nairobi Ethics and Research Committee Telephone No. 2726300 Ext. 44102 email uonknh_erc@uonbi.ac.ke.

Participant's statement

I have read this consent form or had the information read to me. I have had the chance to discuss this research study with a study counselor. I have had my questions answered in a language that I understand. The risks and benefits have been explained to me. I understand that my participation in this study is voluntary and that I may choose to withdraw any time. I freely agree to participate in this research study.
I understand that all efforts will be made to keep information regarding my personal identity confidential.

By signing this consent form, I have not given up any of the legal rights that I have as a participant in a research study.

I agree to participate in this research study: Yes   No

I agree to provide contact information for follow-up: Yes No

Participant's Name: ____

Participant signature / Thumb stamp _______________________

Date _______________

Researcher's statement

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has willingly and freely given his/her consent.

Researcher's Name: Dr. Saadia Ahmed Guhad__

Date: _______________

Signature ____

1 B. Informed Consent Form – SWAHILI

MAELEZO KUHUSU UTAFITI/WARAKA WA IDHINI

Ningependa ushiriki katika utafiti tunaofanya, mada ni: **Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Refill Stations in Selected Estates in Nairobi County.** Watafiti: Dkt. **Saadia Ahmed**, Dkt. **Winnie Mutai** na Prof. **Julius Oyugi** watafanya utafiti huo.

Madhumuni ya fomu hii ya idhini ni kukupa taarifa utakayohitaji ili kukusaidia kuamua kama utashiriki au kutoshiriki katika utafiti, hatari na manufaa yanayoweza kutokea, haki zako kama mtu wa kujitolea na kitu kingine chochote kuhusu utafiti au fomu hii. hilo haliko wazi. Ukishaelewa na kukubali kuwa katika utafiti, tutakuomba utie sahihi jina lako kwenye fomu hii.

Hizi ndizo kanuni za jumla ambazo washiriki wote katika utafiti wa matibabu wanapaswa kuelewa:

I. Uamuzi wako juu ya ushiriki ni wa hiari kabisa

II. Unaweza kujiondoa kwenye utafiti wakati wowote bila kutoa sababu ya kujiondoa kwako

III. Kukataa kushiriki katika utafiti hakutaathiri huduma ambazo una haki ya kutoa kwenye kioski chako cha kuuza maji.

Utafiti huu unahusu nini?

Tunafanya utafiti ili kubaini ubora wa kibayolojia wa maji ya kunywa ya chupa kutoka kwa vituo vya kujaza maji katika maeneo maalum katika Kaunti ya Nairobi.

Je, nini kitatokea ukiamua kuwa katika utafiti huu?

Ukikubali kushiriki katika utafiti huu, mambo yafuatayo yatafanyika;

- Tutakuuliza maswali machache ambayo yatachukua takriban dakika tano.
- Maswali yatakuwa kuhusu chanzo cha maji kwa muuzaji, taratibu za kutibu maji, utunzaji, usafirishaji na matengenezo ya jumla ya usafi wa maji.

Je, kuna hatari zozote, hudhuru usumbufu unaohusishwa na utafiti huu?

Unaweza pia kujisikia vibaya unapojibu baadhi ya maswali. Ikiwa kuna maswali yoyote ambayo hutaki kujibu unaweza kuyaruka. Una haki ya kukataa maswali yoyote yaliyoulizwa wakati wa kuendesha utafiti.

Je, taarifa zangu za kibinafsi zitalindwaje?

Taarifa tunazokusanya kutoka kwako zitasalia kuwa siri. Hili litafikiwa kupitia matumizi ya nambari ya msimbo ili kukutambua katika hifadhidata ya kompyuta iliyolindwa kwa nenosiri na tutaweka rekodi zetu zote za karatasi kwenye kabati ya faili iliyofungwa.

Je, kuna manufaa yoyote ya kuwa katika utafiti huu?

Huenda usinufaike moja kwa moja, hata hivyo, maelezo utakayotoa yatatusaidia kuelewa vyema usalama wa maji ya kunywa na kupitia mapendekezo yetu, watunga sera wataweza kutunga sera zenye ujuzi kuhusu usalama wa maji ya kunywa. Habari hii ni mchango kwa sayansi.

Je, ikiwa una maswali katika siku zijazo?

Ikiwa una maswali zaidi kuhusu kushiriki katika utafiti huu, tafadhali piga simu au tuma masaji ya maandishi kwa mpelelezi mkuu:

Dkt. **Saadia Ahmed Guhad** Mawasiliano: +254716660949, Barua pepe: saadiayguhad@gmail.com

Dkt. **Winnie Mutai, Mawasiliano**: 0724886584, Barua pepe: winny@uonbi.ac.ke

Prof. **Julius Oyugi, Mawasiliano**: 0713898564, Barua pepe: julias.oyugi9@gmail.com

Kwa maelezo zaidi kuhusu haki zako kama mshiriki wa utafiti unaweza kuwasiliana na Katibu/Mwenyekiti, Hospitali ya Kitaifa ya Kenyatta-Kamati ya Maadili na Utafiti ya Chuo Kikuu cha Nairobi Nambari 2726300 Ext. 44102, Barua pepe: uonknh_erc@uonbi.ac.ke.

Kauli ya mshiriki

Nimesoma fomu hii ya idhini au nimesomewa maelezo. Nimepata nafasi ya kujadili utafiti huu na mshauri wa utafiti. Nimejibiwa maswali yangu kwa lugha ninayoielewa. Hatari na faida zimeelezewa kwangu. Ninaelewa kuwa ushiriki wangu katika utafiti huu ni wa hiari na kwamba ninaweza kuchagua kujiondoa wakati wowote. Ninakubali kwa uhuru kushiriki katika utafiti huu wa utafiti.

Ninaelewa kuwa juhudi zote zitafanywa ili kuweka taarifa kuhusu utambulisho wangu wa kibinafsi kuwa siri.

Kwa kutia saini fomu hii ya idhini, sijaacha haki zozote za kisheria nilizo nazo kama mshiriki katika utafiti wa utafiti.

Ninakubali kushiriki katika utafiti huu: **Ndiyo** **Hapana**

Ninakubali kutoa maelezo ya mawasiliano kwa ufuatiliaji: **Ndiyo** **Hapana**

Jina la mshiriki: ____

Sahihi ya mshiriki / mhuri ya kidole gumba ___________________________________

Tarehe _______________

Kauli ya mtafiti

Mimi, niliyetia sahihi chini, nimeeleza kikamilifu maelezo muhimu ya utafiti huu kwa mshiriki aliyetajwa hapo juu na ninaamini kuwa mshiriki ameelewa na ametoa ridhaa yake kwa hiari na kwa uhuru.

Jina la Mtafiti: ______ Dk. Saadia Ahmed Guhad**_______**

Tarehe: _______________

Sahihi ____

2 A. Questionnaire

1. What is your source of water?

   Spring water

   Bore hole

   Well

   Tap water

   Surface water (Lake, Dam/Water Reservoir)

2. Is there standardized operating procedures (SOP)?

   Available   Not available

3. Do you own certificate of good hygiene and sanitation?

   Owned   Not owned

4. Are the water storage and distribution systems well maintained to avoid water contamination?

   Yes   No

5. Are you (or staff) trained on effective methods of providing water hygiene?

   Yes   No

6. How often do you run out of drinking water supply?

   Very often   Often   Sometimes   Rarely   Never

7. Is your water vending facility designed in order to be easily and hygienically used and maintained?

   Yes   No

8. Are the toilets you use situated at the right place?

   In separate blocks   Same block as the drinking water facility

9. Are regular inspections and control of flies and other insects done?

Yes No

10. Do you have handwashing facilities (water and soap) close by the toilets?

Yes No

11. Do you have a correctly built drainage system for wastewater?

Yes No

12. Is the drainage system for wastewater well maintained?

Yes No

2 B. Questionnaire/ Hojaji

1. Chanzo chako cha maji ni kipi?

Maji ya chemchemi

Shimo la shimo

Kisima

Maji ya bomba

Maji ya uso (Ziwa, Bwawa / Hifadhi ya Maji)

2. Je, kuna taratibu sanifu za uendeshaji (SOP)?

Inapatikana

Haipatikani

3. Je, unamiliki cheti cha usafi na usafi wa mazingira?

Inayomilikiwa

Haimilikiwi

4. Je, mifumo ya kuhifadhi na kusambaza maji imetunzwa vyema ili kuepuka uchafuzi wa maji?

Ndiyo

Hapana

5. Je, wewe (au wafanyakazi) wamefunzwa kuhusu mbinu bora za kutoa usafi wa maji?

Ndiyo

Hapana

6. Ni mara ngapi unakosa maji ya kunywa?

Mara kwa mara

Mara nyingi

Mara nyingine

Nadra

Kamwe

7. Je, kituo chako cha kuuzia maji kimeundwa ili kutumika na kudumishwa kwa urahisi na kwa usafi?

Ndiyo

Hapana

8. Je, vyoo unavyotumia viko mahali pazuri?

Katika vitalu tofauti

Kitalu sawa na kituo cha maji ya kunywa

9. Je, ukaguzi na udhibiti wa mara kwa mara wa nzi na wadudu wengine hufanywa?

Ndiyo

Hapana

10. Je, una vifaa vya kunawia mikono (maji na sabuni) karibu na vyoo?

Ndiyo

Hapana

11. Je, una mfumo wa mifereji ya maji uliojengwa kwa usahihi kwa maji machafu?

Ndiyo

Hapana

12. Je, mfumo wa mifereji ya maji kwa maji machafu umetunzwa vizuri?

Ndiyo

Hapana

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Ref: KNH-ERC/A/106

15th March, 2022

KENYATTA NATIONAL HOSPITAL
APPROVED
15 MAR 2022
KNH/UoN-ERC
P. O. Box 20723 - 00202 NAIROBI

Dr. Saadia Ahmed Guhad
Reg. No. W64/11925/2018
Institute of Tropical & Infectious Diseases (UNITID)
Faculty of Health Sciences
University of Nairobi

Dear Dr. Guhad,

RESEARCH PROPOSAL: BACTERIOLOGICAL EVALUATION AND QUALITY ASSESSMENT OF DRINKING WATER FROM WATER REFILL STATIONS IN SELECTED ESTATES IN NAIROBI COUNTY (P984/12/2021)

This is to inform you that KNH-UoN ERC has reviewed and approved your above research proposal. Your application approval number is **P984/12/2021.** The approval period is 15th March 2022 – 14th March 2023.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by KNH-UoN ERC.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to KNH-UoN ERC 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH-UoN ERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to KNH-UoN ERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely,

DR. BEATRICE K.M. AMUGUNE
SECRETARY, KNH-UoN ERC

c.c. The Dean, Faculty of Health Sciences, UoN
The Senior Director, CS, KNH
The Chairperson, KNH- UoN ERC
The Assistant Director, Health Information, KNH
The Director, Institute of Tropical & Infectious Diseases (UNITID), UoN
Supervisors: Ms. Winnie Mutai, Dept. of Medical Microbiology UoN
Prof. Julius Oyugi, Dept. of Medical Microbiology & UNITID, UoN

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **640228**

Date of Issue: **21/July/2022**

RESEARCH LICENSE

This is to Certify that Dr.. Saadia Ahmed Guhad of University of Nairobi, has been licensed to conduct research in Nairobi on the topic: Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Refill Stations in Selected Estates in Nairobi County for the period ending : 21/July/2023.

License No: **NACOSTI/P/22/19020**

640228

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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MINISTRY OF HEALTH

Telephone: Nairobi 254-020-2725601/4
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Email:headnphl@nphl.go.ke
When replying please quote:

NATIONAL PUBLIC HEALTH
LABORATORY SERVICES
P.O BOX 20750-00200
NAIROBI, KENYA

25/05/ 2022

Dr. Saadia Ahmed Guhad
P.O.BOX 7278-00610
NAIROBI

REF: Approval of your Research Application at National Public Health Laboratory

Reference is made to your application on the above subject.

This is to notify you that the National Public Health Laboratory Research Committee reviewed your research application on the topic entitled **"Bacteriological Evaluation and Quality Assessment of Drinking Water from Water Refill Stations in Selected Estates in Nairobi County."**

We are happy to inform you that the committee approved the application and you will be attached at the National Microbiology Laboratory for your research.

You are adviced to liase with the laboratory Manager **Ms. Jedidah Kahura** for further directions.

She can be reached on the following contacts; Email- **jedidahkahura@yahoo.com**, Phone number- **+254722849605**.

Rosebella Kiplagat
Chair- National Public Health Laboratory Research Committee

Copy to: Manager National Microbiology Reference Laboratory