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**Original Research Article**

# Bacteriological quality of drinking water for Masinga-Kitui water supply system, Kenya

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## ABSTRACT

**Background:** Increasing population has led to increased water demand in major towns across the world. This study focused on Kitui Town in Kenya where about 80% of the inhabitants depend on Masinga-Kitui water supply system. There are limited alternative water sources including groundwater that are not reliable due high contamination with coliforms. The aim of this study was to determine bacteriological quality of Masinga-Kitui water and establish the potential sources of contaminants.
**Methods:** A total of 90 water samples were collected for analysis whereby, 72 were from the households' water storage facilities selected through stratified purposive sampling technique. Additional 18 samples were representatively collected from the main distribution network/including two community water points located in Kitui Town (Kalundu and Bondeni). Water quality analysis was performed at Kenya Water Institute water laboratory in Nairobi.
**Results:** All the analyzed water samples were grossly contaminated with *E. coli* and total Coliforms which exceeded the acceptable WHO/KEBS limit of zero (0) CFU/100 ml of water sample. Majority of the Kitui Town residents associated poor water quality with poor sanitation, poor waste management, poorly maintained sewage and waste waters, contamination of water at the main distribution tank at Kwa-Ngindu, poor water storage at the household and unhygienic practices. About 34% of Kitui residents were at the risk of contracting waterborne diseases due to consumption of contaminated water.
**Conclusions:** Regular monitoring of water quality, surveillance of Masinga-Kitui water infrastructure, and enhanced awareness programme should be adopted to encourage Kitui residents to treat drinking water.

**Keywords:** Bacteriological assessment, Water quality, Drinking water, Water supply system

## INTRODUCTION

The world health organization states that any chemical, biological, physical agent that affects the quality of water is potential to cause health problems to the consumer.[1] It is estimated that 1.8 billion people use unsafe water. Existence of fecal contaminated water accounts for 53% in Africa and 35% in East Asia.[2] About 4 billion cases of diarrhea and 2.2 million deaths recorded each year are as a result of consumption of unsafe water, where children under the age of five are the most affected.[3] Residents in urban areas in the developing world are also at the risk of water-borne and communicable diseases attributed to consumption of contaminated water in the supply systems.[4,5] The situation has been deteriorating due to the increasing population and limited supply of clean and safe drinking water.[6,7] These challenges hinder meeting the SDGs in the urban set-ups in most of the developing countries including Kenya.[8,9] Different sources of drinking water subjects many lives to health threats due to

contamination of water involving both organic as well as inorganic substances.[10] Outbreaks of waterborne diseases have been recorded where infectious microorganisms intrude in the water supply system.[1] One of the most common infectious microorganisms are as results of fecal contamination.[1] Research shows that most developing countries draw water from seasonal streams and rivers which are highly prone to contamination by leaking sewerage lines, human and animal excreta flowing into open drains and also affecting drinking water distribution systems.[11] Such contamination of drinking water through micro-organisms has triggered discussions on matters of public health.[12] According to the World Health Organization, *E. coli* is considered as the main indicator of fecal contamination which signifies presence of fecal pathogens in water.[12,13] Proper monitoring of fecal contamination in a system may give an alert of potential problems in the water supply system such as intrusion of contaminants or existence of pathogens in a drinking water system.[14] In order to completely eliminate the microorganisms from drinking water supply systems priority is usually given to the elements that are believed to have severe and fatal health problems.[15] Most of the major towns in Kenya rely on the municipal water supplies for their domestic uses.[16] A majority of Kitui residents depend on Masinga-Kitui water supply system that is managed by Kitui Water and Sewerage Company (KITWASCO). The other alternative sources of drinking water for example groundwater which is drawn from boreholes, shallow wells, and sand dams are prone to fecal contamination.[4,17] Masinga-Kitui water supply system is a long water pipeline network that runs through two counties in a 75km stretch. Such a long network is prone to sabotage and may have sections where water gets contaminated due to ingression of human and animal waste, poorly maintenance and water rationing due to high demand.[18] such problems cannot be known unless proper surveillance of the pipeline and water quality examined. The aim of this study was to establish the bacteriological quality of Masinga-Kitui water and find out the households and infrastructural conditions underpinning the quality of piped water in Kitui Town.

## METHODS

### *Description of the study area*

This study was conducted in Kitui Town and along Masinga-Kitui water pipeline running from Masinga Dam, Machakos County to Kitui Town, Kitui County. The area is located between 1.375°S and 38.02°E in Kenya (Figure 1). The average elevation in the town is approximately 1152 meters above the sea level. The hilly ridges are observed at the central region of the area while the rest of the areas fall between 600 and 900m above sea level. Masinga-Kitui water supply pipeline serves majority of the government offices, health facilities, hotels and residential areas with a capacity of 9,000 cubic meters per day. The supply is managed by Kitui water and sewerage company (KITWASCO) which is licensed and regulated by water services regulatory board (WASREB) as the water service provider (WSP) for Kitui residents. The alternative water sources from the boreholes and shallow wells are not reliable due to high contamination and high salinity levels. The supply harvests its water from Masinga reservoir in Machakos County which is located 75 km from Kitui Town.

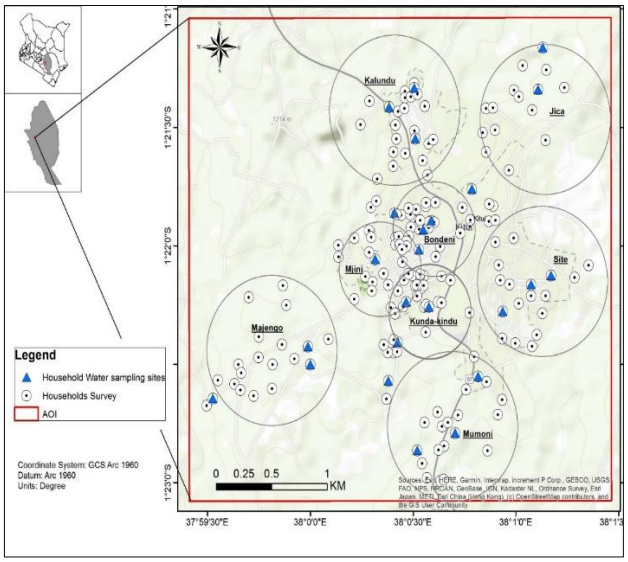



**Figure 1: Location of the study area and distribution of study points in Kitui town.**

### *Sampling and sample size*

This study adopted an analytical cross-sectional research design. The study involved five groups of study population where the first group included the residents of Kitui Town distributed in eight main residential areas (Figure 1). The second group included the operators of the community water points (CWPs) located within Kitui Town. The four other target groups included the managers at Masinga reservoir (main source), Masinga water treatment plant, operators of the reservation tanks at the mid-way distribution station, and at the main distribution tank at Kwa-Ngindu in Kitui Town. The number of households in Kitui Township area covering eight residential areas namely; Mjini, Majengo, Kunda-Kindu, Kalundu, Bondeni, Jica, Site and Mumoni was 16,111.[19] Stratified sampling technique was applied to select the households from different residential areas that were used to gather information to establish associated practices that contributed to water contamination. The respondents from these residential areas were selected through purposive sampling. The number of respondents was determined using following equation.[20]

$$n = (Z^2pq)/d^2$$

Where; n is the desired sample size when the target population is greater than 10,000, Z is the standard normal deviation of 1.96 which corresponds to 95% confidence level, P is the expected prevalence of

proportion where; q is equal to (1-p) and d is the defined level of statistical significance. Therefore, sample size was calculated as 138 which was rounded off to 140 households. However, an additional 30% (46 respondents) were included in the study to account for non-responses and to consider households in close proximity to known source of contamination that were not described in the criteria for site selection, and others in areas known for frequent water outages. These special considerations in water sampling in a public system are recommended by the US center for disease control and prevention.[21] Therefore, this study involved a total of 184 respondents distributed in the eight residential areas in Kitui Town as shown in (Table 1).

**Table 1: Distribution of households' respondents and the number of water samples collected.**

| Site no. | Residential area | No. of HHs | HH Sample size | No. of water samples |
|---|---|---|---|---|
| **1** | Bondeni | 1,298 | 15 | 9 |
| **2** | Mumoni | 1,080 | 12 | 9 |
| **3** | Jika | 1,675 | 19 | 9 |
| **4** | Majengo | 2,361 | 27 | 9 |
| **5** | Mjini | 3,467 | 40 | 9 |
| **6** | Kalundu | 3,304 | 38 | 9 |
| **7** | Kunda Kindu | 1,130 | 13 | 9 |
| **8** | Site | 1,796 | 20 | 9 |
| **Total** | | 16,111 | 184 | 72 |

*Households population data compiled from KNBS (2019).

***Collection of water samples and analysis***

Collection of water samples from the field was done monthly between November, 2021 and January, 2022. Collection of water samples was done following the American Public Health Association standards.[22] Well labeled sterilized 500ml glass bottles were used to collect samples for bacteriological water quality analysis. The water sample bottles were thoroughly washed using hot water and detergent and rinsed with distilled water before autoclaving at 121ºC for 15 minutes.[23] Sodium thiosulfate (1ml of 10% $Na_2S_2O_3$) was added to each sample bottle to neutralize any residual chlorine present in the sample.[24] A total of 90 water samples were collected for analysis whereby, 3 water samples were collected monthly from each of the eight residential areas in Kitui Town (Table 3.1). A total of 72 samples were collected from the households' water storage facilities and 18 samples from the water distribution network/infrastructure that is; 6 samples from Masinga station (before and after treatment), 3 from the reservation tank at Katheka and 3 from the main distribution tank at Kwa-Ngindu, and 6 samples from two community water points (at Kalundu and Bondeni).

The collected water samples were transported within 6 hours to Kenya Water Institute (KEWI) Laboratory in Nairobi Kenya for bacteriological analysis. Samples were carried in a cooler box with ice parks to maintain a temperature of 4˚C.[25] Water quality assessment was done with reference to WHO guidelines.[13] Defined Substrate Technology (DST) was applied to detect and enumerate Total Coliforms and *Escherichia coli* directly in the water samples. About 100ml water sample was mixed with colilert-18 reagent. The sample mixture was gently poured into a quanti-tray while tapping the small wells to release any air bubbles. The sample-filled quanti-trays were then placed onto the quanti-tray rubber and inserted into the quanti-tray sealer with the well side of the quanti-tray facing down as per quanti-tray sealer instructions. A mark pen was used to carefully label the quanti trays then incubated for 18 hours at 35˚C. After the 18 hours, the large and small bright yellow cubes/wells were counted separately. Results were read using the quanti-tray/2000 MNP table to find CFU for Total coliforms. Any positive Total-Coliform quanti tray, was exposed to a UV light. Fluorescence in the wells indicated the presence of *E. coli*. Large and small fluorescent wells were counted and same table referred to get the concentration in CFU per 100mls of water sample. All the data generated from the laboratory procedures were compiled and organized in a Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS Version 24). Descriptive statistics were computed to understand the quantitative data while correlation analysis was done using Pearson's correlation coefficient (r) and the analysis of variance (ANOVA) to establish the relationships between variables. Regression coefficient was generated through a simple regression model to enable interpretation of water quality variables.

## RESULTS

***Bacteriological quality of water in the distribution system***

The results of the bacteriological assessment of water in the main distribution system is depicted in (Table 2). According to the analyzed water samples, Masinga-Kitui water was highly contaminated with extremely high concentrations of total Coliforms beyond the WHO/KEBS permissible level of 0 CFU/100 ml. Water samples collected from Masinga reservoir/dam, at Katheka, Kwa Ngindu, and from the two Community water points (Kalundu and Bondeni) in Kitui Town indicated high levels of total coliforms and fecal contamination (Table 2). The two communal water points were highly contaminated with FC with an average count of 1215.3 CFU/ml detected at Kalundu CWP. This level of contamination was twice the mean value of FC detected at the main source, Masinga reservoir (666.7 CFU/ml). Bondeni CWP showed a lower FC count of 465.3 CFU/ml. Presence of both FC and TC was detected in the water samples collected from the main distribution reservoir/tank at Kwa-Ngindu. The water samples collected immediately after treatment at the Masinga station and Katheka reservoir did not contain fecal

coliforms. This is an indication that water treatment was quite effective in eliminating fecal coliforms. The results presented in Table 2 show 100% contamination of water with Total Coliforms in all the sites. The mean TC count ranged between 808-2420 CFU/100ml which was significantly above the WHO /KEBS permissible limit of 0 CFU/100 ml for drinking water (p=0.001) (Table 2).

**Table 2: Bacteriological analysis of water in the Masinga-Kitui water supply infrastructure.**

| Sampling site | *E. Coli*, (CFU/ml) | | | Total Coliform count (CFU/100 ml) | | |
|---|---|---|---|---|---|---|
| | Mean | Min | Max | Mean | Min | Max |
| **Intake before treatment (BT)** | 666.7 | 14 | >2420 | 2420 | 2420 | >2420 |
| **After treatment (AT)** | 0.0 | 0 | 0 | 808 | 3 | >2420 |
| **Katheka reservoir** | 0.0 | 0 | 0 | 1613 | 0 | >2420 |
| **Kwa-Ngindu reservoir** | 185.3 | 3 | 548 | 2420 | 2420 | >2420 |
| **CWP 1-Kal** | 1215.3 | 23 | >2420 | 2420 | 2420 | >2420 |
| **CWP 2-Bon** | 465.3 | 276 | >2420 | 2420 | 2420 | >2420 |
| **KEBS** | 0 | 0 | 0 | 0 | 0 | 0 |
| **WHO** | 0 | 0 | 0 | 0 | 0 | 0 |

Data presented in the table represent the average values of the measured parameters of the water samples

**Table 3: Environmental Factors associated with Masinga-Kitui water quality in Kitui Town**

| Communal water infrastructure challenges | N | % |
|---|---|---|
| **Water theft/ illegal connections** | 44 | 24 |
| **Poor solid waste management** | 72 | 39 |
| **Lack of proper waste water management** | 123 | 67 |
| **Poorly maintained sewage facilities** | 100 | 54 |
| **Lack of well-designed sanitary facilities** | 46 | 25 |
| **Rationing and/or Lack of enough water supply** | 130 | 71 |
| **Poorly maintained water storage facilities** | 74 | 40 |
| **High cost of water treatment** | 26 | 14 |
| **Broken and poorly maintained water supply pipes** | 88 | 48 |
| **Industrial waste in the streets** | 11 | 6 |
| **Other challenges** | 6 | 3 |

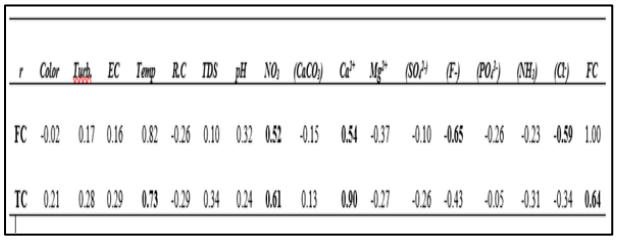
**Table 4: Bacteriological quality analysis of the households' water in various residential areas in Kitui Town.**

| Residential areas | Sample sites | *E. Coli*, (CFU/ml) | TC (CFU/100 ml) | Residential areas | Sample | *E. Coli*, (CFU/ml) | TC (CFU/ 100 ml) |
|---|---|---|---|---|---|---|---|
| **Majengo** | Maj-07 | 75.3 | 2420 | Kalundu | Kal-12 | 303.3 | 2420 |
| | Maj-10 | 919.3 | 2420 | | Kal-05 | 502.7 | 2420 |
| | Maj-20 | 651.3 | 2420 | | Kal-16 | 773.3 | 2420 |
| **Mjini** | Mji-03 | 33.0 | 2420 | Jica | Jic-04 | 1662.3 | 2420 |
| | Mji-17 | 351.3 | 2420 | | Jic-06 | 65.3 | 2420 |
| | Mji-27 | 336.7 | 2420 | | Jic-14 | 143.3 | 2420 |
| **Kunda Kindu** | Kunda-03 | 81.3 | 2420 | Site | Sit-03 | 213.3 | 2420 |
| | Kunda-10 | 295.3 | 2420 | | Sit-06 | 380.0 | 2420 |
| | Kunda-12 | 991.7 | 2420 | | Sit-09 | 1005.0 | 2420 |
| **Bondeni** | Bon-06 | 281.3 | 2420 | Mumoni | Mumo-01 | 45.0 | 1842 |
| | Bon-10 | 224.3 | 2420 | | Mumo-06 | 476.0 | 1609 |
| | Bon-01 | 1201.7 | 2420 | | Mumo-12 | 140.7 | 2420 |

The data shows the mean concentration values.

The five most common environmental challenges perceived to reduce water quality in Kitui Town is represented in (Figure 2). These challenges included; water rationing and limited supply to the households (71%, lack of proper waste water management in Kitui town (67%), poorly maintained sewage facilities (54%), broken and poorly maintained water supply pipes (48%) and lack of proper maintenance and cleaning of water

storage facilities (40%). Microbial contamination of water in the supply system was perceived to be caused by poor solid waste and wastewater management and poor maintenance of sewage and water infrastructure in Kitui Town.



| r | Color | Turb. | EC | Temp | R.C | TDS | pH | $NO_3$ | ($CaCO_3$) | $Ca^{2+}$ | $Mg^{2+}$ | $(SO_4)^{2-}$ | ($F^-$) | ($PO_4^{3-}$) | ($NH_3$) | (Cl) | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FC | -0.02 | 0.17 | 0.16 | 0.82 | -0.26 | 0.10 | 0.32 | **0.52** | -0.15 | **0.54** | -0.37 | -0.10 | **-0.65** | -0.26 | -0.23 | **-0.59** | 1.00 |
| TC | 0.21 | 0.28 | 0.29 | **0.73** | -0.29 | 0.34 | 0.24 | **0.61** | 0.13 | **0.90** | -0.27 | -0.26 | -0.43 | -0.05 | -0.31 | -0.34 | **0.64** |

**Figure 2: Relationship between physio-chemical quality of water and concentration of coliforms.**

The key Informants informed this study that water quality checks were carried out on weekly basis especially at the communal water points (CWP). The KI pointed that bacteriological quality tests were performed once per month while physiochemical quality tests were undertaken twice a month in the distribution system. Despite the quality checks, the supplied water to the Kitui Town residents still showed high level of contamination with a possibility of having unidentified sources of water contamination in the system. The surveillance team also reported that they lacked regular facilitation to carryout water quality checks. This forced them to skip some scheduled water quality checks. This is one of the main problems that limited monitoring of water quality in the system. This study calls for the responsible authority to undertake more regular water quality checks in order to make sure that any contamination of water system is identified at an early stage and the necessary action taken. This study established that the water laboratory at the Masinga quality control station was not fully equipped with the appropriate equipment to carry out detailed water quality analysis. Capital investment is high but a well-equipped laboratory would facilitate frequent water quality monitoring as required by WASREB.

***Bacteriological quality analysis for the households' water***

This study analyzed 72 water samples collected from 24 representative households distributed in eight residential areas in Kitui Town, for bacteriological quality analysis. Due to fecal and microbial contamination detected within the main Masinga-Kitui water supply, the water samples collected from the households were equally (100%) contaminated. The mean concentration values of FC and TC in the household water is shown in (Table 4). According to the results for the analyzed household water samples, the supplied Masinga-Kitui water in all the residential areas in Kitui Town were grossly contaminated with high levels of both FC and TC. The results presented in Table 4 showed significant differences between TC and FC (p=0.001). Apart from few households in Mjini (Mji-03), Majengo (Maj-07), Kunda Kindu (Kunda-03) Jica (Jic-06), and Mumoni area (Mumo-01) where the mean concentration of *E. coli* was below 100 (CFU/ml), the rest of the samples tested relatively high concentration levels of *E. coli.* This implied that most of the households in Kitui Town were at a very high risk of contracting waterborne diseases due to high contamination of drinking water. The mean concentration level of Total Coliforms in all the water samples from the residential areas was more than 1000 CFU/100ml. The results also showed that presence of total coliforms was strongly associated with the level of fecal coliforms in the water (r=0.64) (Figure 2).

## DISCUSSION

Contamination of water has been a major problem in the public water supply systems in many urban areas across the world. To some extent agricultural activities and lack of proper maintenance of water infrastructure in the urban areas have contributed to water contamination in the distribution system especially where broken pipes stay for long without getting repaired.[26] According to the literature, contamination of water at the household level is associated with poor household hygiene.[26,27] Researchers have established that contamination of public water with FC and TC contribute a lot in the outbreaks of waterborne diseases as a result of drinking contaminated and untreated water.[28] This study established that there were very few households where fecal coliforms level was below 100CFU/100ml. Majority of the water samples collected from the households, contained relatively high level of *E. Coli* putting the households at very high risk of consuming contaminated drinking water. This finding concurs with a study undertaken in Uganda where the concentration of total coliforms was higher than fecal coliforms in the analyzed water samples.[29] This calls for a continuous monitoring of water quality in the public water supply systems which is key in the detection of sources and causes of water contamination to reduce the risks of waterborne diseases.[30] From the information gathered from the Key Informants, this study established that frequent bursts and water leakages within the distribution network were potential causes of intrusion of contaminants into the system. Some water supply pipes were as old as 20 years and dilapidated thus to some extent associated with water contamination and frequent water burst in the system during high pressure flows. These findings concur with the results found elsewhere in a similar water supply system.[35] From the field observations and key informants' interviews conducted with the managers and supervisors at different stations, it was established that the high rate of water contamination in the distribution system was linked to poorly maintained water storage facilities. Similar association was identified in another study conducted in Kisii Town and other peri-urban areas in western Kenya.[36,37] High content of Fecal and Total Coliforms in the water was attributed to human and animal waste intrusions into the water supply system.

Turbidity is considered as an important parameter that shows significant influence in microbiological quality of drinking water.[27] From this study, this parameter did not show significant relationship with microbial contamination of household water (r=<0.20) (Figure 2). However, the level of fecal contamination and turbidity varied from one household to the other. According to the WHO/ KEBS guidelines, safe drinking water should have zero presence of coliforms.[13,31,32] This study showed that the level of contamination of water due to presence of total Coliforms and fecal Coliforms was extremely above the permissible limit of 0 CFU/100 ml thus not compliant. This is an indication that drinking water in all the analyzed households water samples in Kitui Town were highly contaminated with coliforms and therefore not safe for drinking. In this study, the most likely source of water contamination at the household levels was linked with already contaminated water sourced from the main distribution tank located at Kwa-Ngindu. This finding concurs with the study conducted in Ethiopia by Tabor and others who found that the hygiene condition of the main distribution tank in the public water supply system had a lot of influence in the quality of water distributed to the households.[33] The main water storage tanks were not cleaned regularly as required. Particularly, the presence of FC and TC in the water storage at Kwa-Ngindu distribution tank was attributed to droppings of birds and buts that roosted inside the tank. Due to the scope of this study, we were not in a position to explore the kind of total coliforms present in the water to establish possible cause of contamination. However, water contamination at the main Masinga reservoir was attributed to contaminated washout from the agricultural fields and human settlements located near the reservoir. The potential runoff and washout from the farms where fertilizers and animal waste are used for cropping are the possible causes of water contamination in such a point. Through household surveys and Key Informant interviews, this study revealed that deteriorated water quality at the households may be linked to poor water handling hygiene practices at the households. Issues such as failure to clean the water storage facilities, poor sanitation and failure to wash hands regularly when handling water contributed a lot in the contamination of households' water. This study found that poor maintenance of water infrastructure for example failure to clean regularly the water storage facilities and failure to replace dilapidated pipes contributed to water contamination in the residential areas in Kitui Town. Some of the broken/leaking water pipes were observed running through wastewater systems within the residential areas. This also contributed to water contamination in Kitui Town. This finding also concurs with a study conducted on African Countries that made similar observations.[34] Water from the communal water points Kalundu and Bondeni were also grossly contaminated with total Coliforms and fecal Coliforms. The two communal water points received water from Kwa Ngindu main distribution tank where fecal coliforms were first detected in the distribution system. In addition, the two CWPs were located in the informal settlements where overcrowding and poor sanitation were observed. As such, unhygienic conditions including poor solid water management contributed largely to water contamination. This concurs with the results obtained by Daniel and others that the quality of household water was significantly related with the quality of water from the source.[26,28] This study suggests that the issue of contamination of water with coliforms should be investigated following the WHO guidelines in order to identify the key contaminants of water in the distribution network.[32]

## CONCLUSION

This study established that all the water samples collected from the households tested positive with microbial contaminants. About 70% of the analyzed water samples collected from the distribution system tested positive with FC above 100 CFU/100 ml. Water samples collected immediately after treatment at the main source (Masinga water treatment station) and samples from Katheka reservoir were free from fecal coliforms contamination. This implied that water treatment process was effective in eliminating the possible coliforms. The main distribution tank located near Kitui Town at Kwa-Ngindu, was in poor hygienic condition. Accumulated dirt in the tank contributed to deterioration of water quality at that site. All the water samples collected from different sites within the main distribution network tested positive with total Coliforms. This problem contributed to contamination of water supplied to the households and the communal water points in Kitui Town. All the water samples from the households tested positive with both FC and TC. The minimum mean level of FC was 33CFU/100 ml recorded in Mjini (Mji-03) and the maximum of 1662.3 CFU/100 ml recorded in Jica (Jic-04) while the minimum TC was about 1600CFU/100ml. Further, contamination of the household water was associated with poor waste (solid and liquid) management in the residential areas, unhygienic practices at the households, insufficient residual chlorine in the distribution line, incorrect cross-connection of water supply lines, deteriorated water pipeline and frequent water bursts. This study revealed that recontamination of water at the households' may have been contributed by lack of regular cleaning of water storage facilities. Most of the households stored water for at least a day with some storing it for more than a week and used it during downtime of the supply. Regular monitoring of water quality, surveillance of Masinga-Kitui water infrastructure, and enhanced awareness programme should be adopted to encourage Kitui residents to drink treated water.

### *Recommendations*

KITWASCO should ensure optimum chlorine dosage is maintained throughout the water supply system and particularly before the water is released to the consumers. This can mitigate any recontamination that may occur in

the distribution system or at the storage facilities. Secondary booster chlorination can also be installed at designated locations where necessary. The Water Service Provider should undertake prompt repairs & maintenance of the water pipeline and improve public sewer system in Kitui Town. The county government of Kitui and the Municipal management should set new regulations to control waste management in Kitui Town. This improvement will prevent recontamination of water through the broken sections of the pipeline and intrusion of poorly disposed domestic wastewater in the residential areas. Public health department should promote behavior change in the adoption of appropriate household water treatment methods to minimize the risks of waterborne diseases.

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## REFERENCES

1. Pal M, Ayele Y, Hadush M, Panigrahi S, Jadhav VJ. Public Health Hazards Due to Unsafe Drinking Water. Air Water Borne Dis. 2018;7:100-38.
2. Clasen TF, Alexander KT, Sinclair D, Boisson S, Peletz R, Chang HH, et al. Interventions to improve water quality for preventing diarrhoea. Cochrane Database of Systematic Reviews, 2015;10:23-9.
3. Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. PLoS Med. 2014;11(5):23-8.
4. Abila R, Muthangya M, Mutuku E, Mutati K, Munguti M. Physico-chemical and bacteriological quality assessment of shallow wells in Kitui Town, Kenya. J Environ Sci. Water Resources. 2012;1(2):27-33.
5. Duressa G, Assefa F, Jida M. Assessment of bacteriological and physicochemical quality of drinking water from source to household tap connection in Nekemte, Oromia, Ethiopia. J Environ Public Health. 2019.
6. Progress on drinking water and sanitation: Available at: https://apps.who.int/iris/handle/10665/44842. Accessed on 20 November 2021.
7. Nhapi U, Wali BK, Uwonkunda H, Nsengimana NB, Kimwaga R. Assessment of Water Pollution Levels in the Nyabugogo Catchment, Rwanda. Environ Engineer J. 2011;4:40-53.
8. Economic, Financial and Technical Series. Afr Res Bull. 2002;38:11.
9. Darvesh N, Das JK, Vaivada T, Gaffey MF, Rasanathan K, Bhutta ZA. Water, sanitation and hygiene interventions for acute childhood diarrhea: a systematic review to provide estimates for the lives saved tool. J Environ Public Health. 2017.
10. Benedict KM, Reses H, Vigar M, Roth DM, Roberts VA, Mattioli M. Surveillance for waterborne disease outbreaks associated with drinking water United States. MMWR. 2017;66(44):1216-21.
11. Dwight RH, Fernandez LM, Baker DB, Semenza JC, Olson BH. Estimating the economic burden from illnesses associated with recreational coastal water pollution-a case study in Orange County, California. J Environ Manage. 2005;76:95-103.
12. Nel N, Parker A, Silbernagl P. Improving water quality in storm water and river systems: an approach for determining resources. J South Afr Institution Civil Engineer. 2013;55(1):22-35.
13. Guidelines for drinking water quality. Available at: https://www.who.int/publications/i/item/9789241549950. Accessed on 20 November 2021.
14. Ameya G, Olifan Z, Abdulhakim M, Adugna A, Birhanie A. Bacteriological quality of drinking water obtained from main sources, reservoirs and consumers tap in Arba Minch Town, Southern Ethiopia. Afr J Microbiol Res. 2018;12(24):567-73.
15. Minda BN. Assessment of drinking water quality and related health risks in Adama Town. Available at: https://www.academia.edu/91512835/Assessment_of_physico_chemical_and_bacteriological_quality_of_drinking_water_at_sources_and_households. Accessed on 20 November 2021.
16. Kimani-Murage EW, Ngindu AM. Quality of Water the Slum Dwellers Use: The Case of a Kenyan Slum. J Urban Health. 2007;84(6):829-38.
17. Adejuwon J, Mbuk C. Biological and physiochemical properties of shallow wells in Ikorodu Town, Lagos Nigeria. Geol. 2011;3:161-8.
18. Suthar S, Chhimpa V, Singh S. Bacterial contamination in drinking water: a case study in rural areas of northern Rajasthan, India. Environ Monitor Assess. 2009;159(1-4):43-50
19. Population by County and Sub-County. Available at: https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county. Accessed on 20 November 2021.
20. Mugenda OM, Mugenda AG. Research Methods: Quantitative and Qualitative Approaches. Nairobi: African Centre for Technology Studies (ACTS) Press. 2003.
21. A guide to conducting household surveys for Water Safety Plans. Available at: https://www.cdc.gov/nceh/ehs/gwash/publications/guide_conducting_household_surveys_for_water_safety_plans.pdf. Accessed on 20 November 2021.

22. Gilcreas FW. Standard methods for the examination of water and waste water. Am J Public Health Nations Health. 1966;56(3):387-8.
23. Drinking water and sanitation; progress on drinking water and sanitation, UNICEF and World Health Organization. Available at: https://www.unicef.org/gambia/Progress_on_drinking_water_and_sanitation_2014.pdf. Accessed on 20 November 2021.
24. Clark I. Sampling and Analysis. Groundwater Geochemistry and Isotopes. USA: CRC Press; 2015: 381-402.
25. Temesgen E, Hameed S. Assessment of physico-chemical and bacteriological quality of drinking water at sources and household in Adama Town, Oromia Regional State, Ethiopia. Afr J Environ Sci Technol. 2015;9(5):413-9.
26. Mesalie RA, Aklog D, Kifelew MS. Failure assessment for drinking water distribution system in the case of Bahir Dar institute of technology, Ethiopia. Applied Water Sci. 2021;11(8):1-24.
27. Akunga DN. Estimating the impact of unsafe water, sanitation and hygiene on the global burden of disease: evolving and alternative methods. Trop Med Int Health. 2014;19(8):884-93.
28. Daniel D, Diener A, van de Vossenberg J, Bhatta M, Marks SJ. Assessing drinking water quality at the point of collection and within household storage containers in the hilly rural areas of mid and far-western Nepal. Int J Environ Res Public Health. 2020;17(7):2172.
29. Agensi A, Tibyangye J, Tamale A, Agwu E, Amongi C. Contamination potentials of household water handling and storage practices in Kirundo sub-county, Kisoro district, Uganda. J Environ Publ Health. 2019.
30. Pietrucha-Urbanik K. Failure analysis and assessment on the exemplary water supply network. Eng Fail Analys. 2015;57:137-42.
31. Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Available at: https://www.who.int/publications/i/item/9789240045064. Accessed on 20 November 2021.
32. Drinking water. Available at: https://www.who.int/en/news-room/fact-sheets/detail/drinking-water. Accessed on 20 November 2021.
33. Tabor M, Kibret M, Abera B. Bacteriological and physio chemical quality of drinking water and hygiene-sanitation practices of the consumers in Bahir Dar city, Ethiopia. Ethiop J Health Sci. 2011;21(1):19-26.
34. Bates VM. The Effect of Infrastructure on Water-Related Diseases in Rural African Communities. Vanderbilt Undergrad Res J. 2012;8:23-8.
35. Dong C, Michael S, Steven BKN. Optimal design of water distribution system to minimize risk of water main breaks in western fort Wayne. Ethiop J Health Sci. 2013.
36. Kioko KJ, Obiri JF. Household attitudes and knowledge on drinking water enhance water hazards in peri-urban communities in Western Kenya. Kenya J Health Sci. 2012;4:1-5.
37. Ondieki JK, Akunga DN, Warutere PN, Kenyanya O. Bacteriological and physicochemical quality of household drinking water in Kisii Town. Kisii County Heliyon J. 2021.

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