

Journal of **Medicine, Nursing & Public Health**



A Comparative Study of Drinking Water Sources and Their Bacteriological Quality in Entebbe Municipality, Uganda

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ISSN: 2706-6606

A Comparative Study of Drinking Water Sources and Their Bacteriological Quality in Entebbe Municipality, Uganda

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How to cite this article: Twongyirwe, J., Kirigwajjo, M., Odoki, M., Musoke, M. M., & Muwanguzi, B. (2026). A Comparative Study of Drinking Water Sources and Their Bacteriological Quality in Entebbe Municipality, Uganda. *Journal of Medicine, Nursing & Public Health*, 9 (2), 26-34.
<https://doi.org/10.53819/81018102t5458>

Abstract

Safe drinking water is essential to public health; however, microbiological contamination remains a concern in urban and peri-urban settings. Residents of Entebbe Municipality rely on multiple drinking-water sources, yet comparative local evidence on their bacteriological quality remains limited. To compare the bacteriological quality of drinking-water sources in Entebbe Municipality by determining the presence and concentrations of *Escherichia coli* and total coliforms and assessing compliance with the bacteriological requirements of WHO and the Uganda National Bureau of Standards (UNBS). A cross-sectional, analytical, laboratory-based study assessed 133 water samples from boreholes, piped water, rainwater, springs and surface water. Samples were collected in sterile 500 mL bottles, transported under cold-chain conditions and analyzed using membrane filtration. A 100 mL aliquot of each sample was filtered through a 0.45 µm membrane, after which the membrane was cultured on blood agar and MacConkey agar. Data were analyzed using SPSS version 20. Pearson's chi-square test assessed associations between water-source type and categorical contamination and compliance outcomes, while the Kruskal–Wallis H test compared bacterial concentrations across source types. Statistical significance was set at $p < 0.05$. The study found of the 133 samples, 106 (79.7%) showed no bacterial growth, while 27 (20.3%) were positive for *E. coli* and/or total coliforms. Surface and spring water had the highest proportions of contamination (40.0% each), followed by rainwater (11.1%), borehole water (4.0%) and piped water (3.8%). Bacterial concentrations ranged from 0 to 4,100 CFU/100 mL, with a mean of 300.33 CFU/100 mL (SD = 897.551). Compliance was highest for piped water (96.2%) and borehole water (96.0%), followed by rainwater (88.9%); spring and surface water had the lowest compliance (60.0% each). Water-source type was significantly associated with contamination ($\chi^2 = 23.057$, $df = 4$, $p < 0.001$), and bacterial concentrations differed significantly among source types ($p < 0.001$). The study concludes that bacteriological quality differed significantly by water-source type. Spring and surface water were the most vulnerable sources, whereas piped and borehole water exhibited better bacteriological quality. Strengthened surveillance, source protection, household water treatment and improved sanitation are therefore warranted, especially for spring and surface-water sources.

Keywords: Drinking water; *Escherichia coli*; total coliforms; bacteriological quality; Entebbe; Uganda; water safety.

<https://doi.org/10.53819/81018102t5458>

1.0 Introduction

Microbiological quality is a critical component of drinking-water safety. *E. coli* is widely used as an indicator of faecal contamination, whereas total coliforms provide a broader indication of sanitary conditions and potential deficiencies in water systems. WHO guidance indicates that *E. coli* should not be detectable in any 100 mL sample of drinking water. The presence of these organisms therefore warrants investigation of potential contamination sources and pathways. Residents of Entebbe Municipality obtain drinking water from piped supplies, boreholes, springs, rainwater-harvesting systems and surface water. These sources differ in their exposure to environmental hazards and in the degree of sanitary protection they provide.

Evidence from Uganda indicates that water quality varies substantially among source types. For example, Wamyil et al. (2023) reported *E. coli* in spring and well water but not in sampled tap water, while research in Kampala identified faecal contamination in urban spring sources. Entebbe lies within the Lake Victoria basin and is affected by urbanization, sanitation pressures and environmental pollution. The dissertation identified limited recent comparative evidence on the major drinking-water sources used within the municipality. Accordingly, this study compared five source categories within the same municipality, focusing on *E. coli*, total coliforms, bacterial concentrations and compliance with WHO/UNBS bacteriological requirements.

2.0 Methods

2.1 Study design and setting

A cross-sectional, analytical, laboratory-based design was used to compare the bacteriological quality of drinking-water sources in Entebbe Municipality, Wakiso District, Uganda. The study examined five source categories: boreholes, piped water, rainwater, spring water and surface water.

2.2 Sampling and sample size

A total of 133 water samples were included. Sampling sites were purposively selected to represent commonly used water sources in the municipality. The final analytical sample comprised 25 borehole samples, 26 piped-water samples, 27 rainwater samples, 25 spring-water samples and 30 surface-water samples. All 133 targeted samples were collected and analyzed, yielding a 100% sample collection rate.

2.3 Sample collection and laboratory analysis

Samples were collected in sterile 500 mL bottles. Piped-water taps were allowed to run for approximately 2–3 minutes before sampling; borehole and spring samples were collected directly from the outlets; rainwater was sampled from household storage containers; and surface-water samples were collected slightly below the water surface. The samples were sealed, placed in cool boxes with ice packs at approximately 4°C and transported to the laboratory within six hours of collection.

For bacteriological analysis, 100 mL of each sample was filtered through a sterile 0.45 µm membrane using a vacuum filtration unit. The membrane was then transferred to culture media, including blood agar and MacConkey agar. Media for total coliforms were incubated at 37°C for 24 hours, while *E. coli* detection was conducted under thermotolerant conditions at 44–45°C for 24 hours. Colonies were counted and expressed as CFU/100 mL.

2.4 Data analysis and quality control

Data were coded and analyzed using SPSS version 20. Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarize the results. Pearson’s chi-square test assessed associations between water-source type and contamination and between source type and compliance. The Kruskal–Wallis H test was used to compare bacterial concentrations because the concentration data were not normally distributed. Statistical significance was assessed at $p < 0.05$. Sterile equipment, calibration, timely sample processing, duplicate tests and control samples were used as quality-control measures.

2.5 Ethical considerations

The study was conducted as an academic public health investigation in accordance with the procedures described in the dissertation. This condensed manuscript reports laboratory and environmental findings and contains no identifying information about individual households or sampling points.

3.0 Results

3.1 Overall bacteriological findings

Among the 133 samples, 106 (79.7%) showed no bacterial growth, 21 (15.8%) were positive for total coliforms and 6 (4.5%) were positive for *E. coli*. Overall, 27 (20.3%) samples were classified as positive for *E. coli* and/or total coliforms.

Water source	Positive n	Total n	Positive (%)
Piped water	1	26	3.8
Borehole	1	25	4.0
Rainwater	3	27	11.1
Spring water	10	25	40.0
Surface water	12	30	40.0
Total	27	133	20.3

Table 1. Distribution of positive bacteriological samples by water-source type.

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The association between source type and the presence of *E. coli* and/or total coliforms was statistically significant ($\chi^2 = 23.057$, $df = 4$, $p < 0.001$). Surface and spring water had the highest proportions of positive samples, whereas piped and borehole water had the lowest.

3.2 Bacterial concentration

Bacterial concentrations ranged from 0 to 4,100 CFU/100 mL, with a mean of 300.33 CFU/100 mL and a standard deviation of 897.551. This wide range indicates substantial variability among samples, including samples with no detectable contamination and others with high bacterial loads. The Kruskal–Wallis H test showed a statistically significant difference in the distribution of bacterial concentrations among the five source categories ($p < 0.001$).

3.3 Compliance with bacteriological requirements

Water source	Compliance (%)	Non-compliance (%)
Piped water	96.2	3.8
Borehole	96.0	4.0
Rainwater	88.9	11.1
Spring water	60.0	40.0
Surface water	60.0	40.0

Table 2. Compliance with WHO/UNBS bacteriological requirements by source type.

Overall, 106 (79.7%) samples met the bacteriological criteria applied in the study, while 27 (20.3%) did not comply. Compliance differed significantly by water-source type ($\chi^2 = 23.057$, DF = 4, $p < 0.001$).

3.4 Discussion of the Findings

The study found substantial variation in bacteriological quality across the five water-source categories. One in five samples (20.3%) was positive for *E. coli* and/or total coliforms, indicating that microbiological contamination remained an important concern despite most samples showing no detectable bacterial growth. *E. coli* was detected in 4.5% of samples and is of particular public health concern because its presence indicates possible faecal contamination.

Surface and spring water were the most contaminated sources, with 40.0% of samples from each source testing positive. This pattern is consistent with evidence from Uganda indicating greater vulnerability among less protected water sources. Wamyil et al. (2023) reported *E. coli* in spring and well samples but did not detect it in sampled tap water, while Kiwanuka et al. (2023) documented faecal contamination in Kampala springs and linked it to surrounding sanitation and environmental conditions.

The high proportion of positive surface-water samples may be explained by the direct exposure of surface water to runoff, wastewater, animal waste and other environmental contaminants. The findings therefore indicate that untreated surface water in the assessed setting should not be considered microbiologically safe for direct consumption. Similarly, spring sources are vulnerable when collection points lack adequate protection or are exposed to sanitation and waste-management hazards.

Piped and borehole water exhibited much lower positivity rates (3.8% and 4.0%, respectively) and high compliance (96.2% and 96.0%, respectively). This comparatively better performance may reflect treatment, controlled distribution and greater physical protection. Nevertheless, the detection of positive samples indicates that neither source can be considered consistently safe. Leakage, service interruptions, compromised infrastructure and inadequate sanitary protection may permit contamination. Evidence from Gulu similarly indicated that pollution sources, contamination pathways and failures in sanitary barriers were associated with *E. coli* abundance around groundwater sources.

Rainwater displayed an intermediate pattern, with 11.1% of samples testing positive and 88.9% complying with the applied bacteriological criteria. Rainwater quality is strongly influenced by

roof and gutter cleanliness, collection surfaces, storage conditions and household handling. This finding supports a water safety chain perspective, whereby contamination may occur between collection and consumption.

The significant differences in bacterial concentrations among source types further demonstrate that water-source category was associated not only with the occurrence of contamination but also with its magnitude. Concentrations reached 4,100 CFU/100 mL, indicating that a small proportion of samples carried substantial bacterial loads. The use of both contamination-status and bacterial-concentration measures therefore provides a more complete assessment of bacteriological risk.

Although overall compliance was 79.7%, the 20.3% non-compliance was concentrated mainly in spring and surface water. This pattern supports a risk-based approach in which interventions are prioritized according to source vulnerability rather than treating all water sources identically. The findings are also consistent with broader evidence from Uganda showing that microbiological safety varies according to location, source protection and environmental conditions.

4.0 Public Health Implications

These findings have direct implications for environmental health and water-safety planning in Entebbe Municipality. Spring and surface-water sources should receive priority for sanitary inspection, protection and routine microbiological monitoring. Detection of contamination should trigger investigation of contamination pathways and appropriate corrective action. Households relying on vulnerable sources should be supported to adopt safe household water treatment and storage practices. Even sources with high observed compliance require continued monitoring because contamination may occur through infrastructure failure, handling or storage.

5.0 Conclusions

The bacteriological quality of drinking water in Entebbe Municipality varied significantly according to source type. Of the 133 samples, 27 (20.3%) were positive for *E. coli* and/or total coliforms. Surface and spring water had the highest contamination proportions (40.0% each), while piped and borehole water had the lowest (3.8% and 4.0%, respectively). Bacterial concentrations varied significantly among source types and ranged from 0 to 4,100 CFU/100 mL. Overall compliance was 79.7%, with piped and borehole water showing the highest compliance and spring and surface water the lowest. These findings identify spring and surface water as priority sources for water-safety interventions.

6.0 Recommendations

- Strengthen routine bacteriological surveillance by prioritizing testing of spring and surface-water sources and promptly investigating positive results.
- Protect spring and surface-water sources through regular sanitary inspections, improved drainage, and effective control of waste disposal and reduction of contamination pathways.
- Promote household treatment of water from vulnerable sources through boiling, chlorination, filtration or other approved methods, together with hygienic collection and safe storage.
- Maintain borehole and piped-water infrastructure and investigate microbiological failures despite the high observed compliance of these sources.
- Improve rainwater-harvesting hygiene through regular cleaning of roofs and gutters, use of covered storage containers and appropriate first-flush practices.
- Integrate drinking-water surveillance with broader sanitation, solid-waste management, drainage and environmental-health programmes.

7.0 Limitations

The cross-sectional design assessed water quality during a single sampling period and therefore could not adequately capture seasonal variation. The study focused primarily on *E. coli* and total coliforms and did not provide a comprehensive assessment of chemical and physical parameters or the full range of pathogenic contaminants. The 133 selected samples may not represent every water source in the municipality. In addition, the study primarily assessed water at the source and did not comprehensively evaluate contamination during transportation, household storage and handling.

8.0 Further Research

Future studies should adopt longitudinal designs to compare water quality during rainy and dry seasons; assess physical and chemical parameters alongside microbiological indicators; examine sanitary and environmental predictors of contamination; evaluate water quality from the source to the point of consumption; compare household water treatment methods; and investigate relationships between contaminated water sources and waterborne disease outcomes.

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