



# Assessment of *Escherichia coli* Contamination in Informal Water Sources in Kibera, Nairobi: Prevalence, Drivers, and Implications for Public Health

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## Abstract

Access to clean and safe drinking water remains a major challenge in informal settlements such as Kibera in Nairobi, due to inadequate infrastructure, poor sanitation and reliance on unregulated water sources. This study assessed the prevalence of *Escherichia coli* (*E. coli*) contamination in water sources across 12 villages in Kibera and identified associated risk factors. A total of 72 water samples were collected and analyzed using the membrane filtration method. Overall, 29.2% of the samples were contaminated with *E. coli*, with the highest contamination rates observed in Soweto (66.7%) and Soweto West (50%). Water delivered by trucks (75.0%) and boreholes (36.0%) had higher contamination levels than public supply systems (21.0%). Samples exposed to pollution from sewage (33.0%), public toilets (50.0%), and dusty rooftops (100%) also showed elevated contamination. Additionally, untreated water sources had significantly higher *E. coli* levels (63.6%) compared to chlorinated samples (14.9%) ( $p < 0.0001$ ). These findings highlight the critical influence of water source type, pollution exposure, and treatment practices on microbial water quality. Comprehensive interventions including infrastructure upgrades, regular water quality monitoring, improved sanitation, and promotion of effective household water treatment are recommended.

## Subject Areas

Microbiology

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## Keywords

*Escherichia coli*, Water Contamination, Informal Settlements, Kibera, Public Health

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## 1. Introduction

Access to clean and safe drinking water remains a significant challenge in informal settlements globally. Inadequate infrastructure and poor sanitation contribute to widespread microbial contamination [1]. Kibera, located in Nairobi and one of Africa's largest informal settlements, exemplifies these challenges [2]. With a population nearing one million, the existing water infrastructure is overwhelmed, leading to unequal distribution, frequent shortages and reliance on informal often unregulated water sources. These include vendor kiosks, community-operated water points and privately drilled boreholes, all of which are vulnerable to contamination [3].

Kibera's water supply infrastructure is fragile and frequently compromised by aging pipes, illegal connections and environmental factors such as flooding [2]. These vulnerabilities allow fecal contaminants such as *Escherichia coli* (*E. coli*), a key indicator of fecal pollution according to the World Health Organization to enter the water system [4]. The presence of *E. coli* in drinking water poses serious health risks, including diarrheal diseases, cholera and typhoid fever [5]. These risks are further exacerbated by inadequate sanitation facilities, open sewage drains and improper waste disposal practices [3].

Despite community-led initiatives and innovative solutions such as aerial piping systems and localized chlorination efforts many residents of Kibera continue to experience intermittent water supply and bear high costs for water that may still be unsafe for consumption [6]. The adoption of effective water treatment and safe storage practices remains limited due to economic constraints, low public awareness and persistent infrastructural challenges [7].

This study aimed to evaluate the prevalence of *E. coli* contamination in water sources within Kibera and to identify key risk factors contributing to microbial pollution. The findings are intended to inform targeted strategies to improve water safety, reduce disease burden and promote equitable access to clean water in informal urban settlements.

## 2. Materials and Methods

### 2.1. Study Area

This was a cross-sectional study conducted in the twelve villages in Kibera informal settlements namely: Ayany, Gatwekera, Kianda, Laini Saba, Lindi, Makina, Makongeni, Mashimoni, Olympic, Silanga, Soweto and Soweto West.

### 2.2. Ethical Considerations

Ethical approval to conduct this study was obtained from the Kenya Medical Re-

search Institute's Scientific and Ethics Review Unit under protocol number KEMRI/SERU/CMR/XXX/4968. In addition, a research license was granted by the National Commission for Science, Technology and Innovation, license number NACOSTI/P/24/41471. Written consent was also obtained from the owners of water vending points.

### 2.3. Sample Collection

A total of 72 water samples were aseptically collected from community water points in Kibera informal settlements. To ensure proper representation, six samples were collected per village at approximately 100 m spacing between sampling sites, using a convenience sampling approach. Samples were transported under cold chain conditions (2°C - 8°C) to the National Microbiology Reference Laboratory and processed within 24 hours.

### 2.4. Laboratory Analysis

The standard membrane filtration method was used to detect *E. coli*. For each sample, a 100 mL was filtered through a 0.45 µm pore size filter and incubated on chromogenic coliform agar at 42°C ± 0.5°C for 18 - 24 hours. Presumptive *E. coli* colonies were identified by their characteristic dark blue color and confirmed via Gram staining, sulfur indole motility and triple sugar iron testing. Results were reported as colony-forming units (CFU) per 100 mL. Autoclaved water served as the negative control for membrane filtration, while *E. coli* ATCC 25922 served as the positive control in each step.

### 2.5. Data Analysis

Data was managed using Microsoft Excel and analyzed using Stata version 14.0. Descriptive statistics were computed. Kruskal-Wallis test was used to assess differences in *E. coli* counts by water source, pollution exposure and treatment method.

## 3. Results

### 3.1. Water Source Distribution and Treatment Methods

A total of 72 water samples were collected between 29th July 2024 and 30th July 2024. Most of the samples were obtained from public supply systems (72.2%, n = 52), which indicates strong reliance on centralized water distribution. Boreholes contributed 19.4% (n = 14) of the samples, while water trucks (5.6%, n = 4) and rainwater (2.8%, n = 2) had smaller proportions. **Table 1** provides a summary of these findings.

In terms of water treatment practices chlorination (65.3%) was the most commonly utilized method with only 4.2% of the samples treated using reverse osmosis. However, 30.6% of the samples had not undergone any treatment, potentially increasing their vulnerability to microbial contamination. These findings are summarized in **Table 2**.

Pollution exposure was determined by inquiring from the water vendor and by observation during sample collection. Half of the water samples (50%) were associated with sewage contamination, while 5.6% were linked to proximity to public toilets and 2.8% to dusty rooftops. None of the samples were classified as having more than one pollution source; however, since classification relied on single grab samples and observational indicators, mixed-source contamination may have gone undetected. The remaining 41.7% of samples showed no visible

**Table 1.** Distribution of informal water sources per village.

Distribution of water sources by village	Ayany	Gatwekera	Kianda	Laini saba	Lindi	Makina	Makongeni	Mashimoni	Olympic	Silanga	Soweto	Soweto West	Total	Percentage of total (%)
Public supply	4	5	5	5	3	5	4	5	5	5	2	4	52	72.22%
Borehole	2	1	1		2		2	1	1	1	1	2	14	19.44%
Water truck				1	1	1					1		4	5.56%
Rain											2		2	2.78%
Total samples	6	6	6	6	6	6	6	6	6	6	6	6	72	100%

**Table 2.** Distribution of informal water treatment methods by village.

Treatment methods by village	Ayany	Gatwekera	Kianda	Laini saba	Lindi	Makina	Makongeni	Mashimoni	Olympic	Silanga	Soweto	Soweto West	Total	Percentage of total (%)
Chlorination	4	4	4	5	3	4	4	5	3	5	2	4	47	65.28%
No treatment	2	1	2	1	3	2	1	1	2	1	4	2	22	30.56%
Reverse osmosis		1					1		1				3	4.17%

**Table 3.** Distribution of informal water pollution sources by village.

Distribution of pollution by village	Ayany	Gatwekera	Kianda	Laini saba	Lindi	Makina	Makongeni	Mashimoni	Olympic	Silanga	Soweto	Soweto West	Total	Percentage of total (%)
Sewage	1	4	5	4	4	2		2	5	4	4	1	36	50.00%
Public toilet					1			2		1			4	5.56%
Dusty rooftop											2		2	2.78%
None	5	2	1	2	1	4	6	2	1	1		5	30	41.67%

association with any identifiable pollution source. **Table 3** provides a summary of these findings.

### 3.2. *E. coli* Contamination

#### 3.2.1. Descriptive Statistics of *E. coli* Counts

*E. coli* concentrations in water samples ranged from 0 to 87 colony-forming units (CFU) per 100 mL. The mean concentration was 4.5 CFU/100 mL, while both the median and mode were 0 CFU/100 mL, indicating that more than half of the samples had no detectable *E. coli*. The interquartile range was 1 CFU/100 mL, suggesting that the middle 50% of the data points were clustered at low concentration levels.

#### 3.2.2. Distribution of *E. coli* Contamination by Village, Water Source, Pollution Source, and Treatment Method

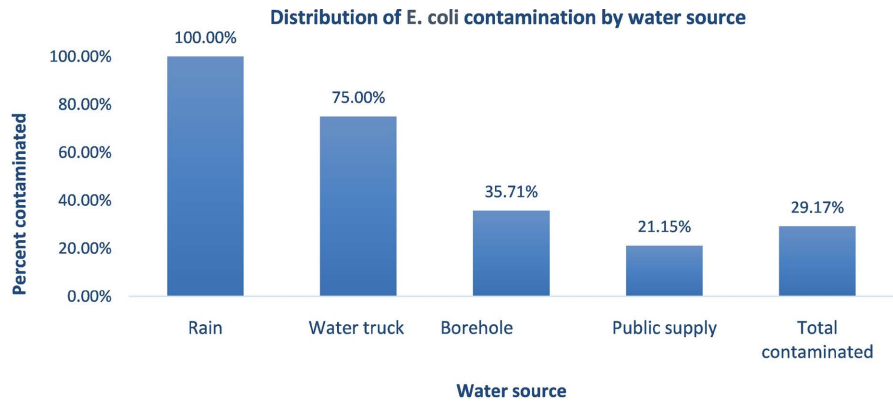
Among the 72 water samples analyzed, (29.2%, n = 21) were contaminated with *E. coli*, defined as having CFUs greater than zero. The contamination rates varied significantly across villages. Soweto had the highest contamination rate at 66.7%, followed by Soweto West at 50%. Makina, Makongeni, Olympic, and Silanga each reported contamination rates of approximately 33%, while the remaining villages exhibited lower rates around 16.7%. These findings, presented in **Table 4**, reveal localized contamination risks and underscore the need for targeted water quality interventions in specific areas.

**Table 4.** Distribution of *E. coli* contamination per village.

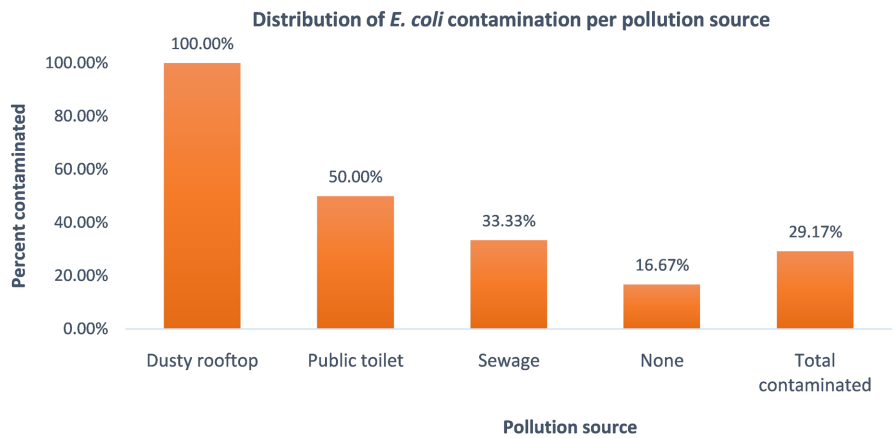
Contamination by village	Ayany	Gatwekera	Kianda	Laini saba	Lindi	Makina	Makongeni	Mashimoni	Olympic	Silanga	Soweto	Soweto West	Total	Percentage
Uncontaminated	5	5	5	5	5	4	4	5	4	4	2	3	51	70.8%
contaminated	1	1	1	1	1	2	2	1	2	2	4	3	21	29.2%
Total samples	6	6	6	6	6	6	6	6	6	6	6	6	72	
Percentage contaminated by village	16.7%	16.7%	16.7%	16.7%	16.7%	33.3%	33.3%	16.7%	33.3%	33.3%	66.7%	50.0%	29.2%	

Contamination levels were influenced by both the type of water source and exposure to potential pollution sources. Water samples from delivery trucks showed the highest contamination rate (75.0%), followed by boreholes (36.0%) and public supply systems (21.0%). In terms of pollution exposure, samples collected near dusty rooftops had a 100% contamination rate, followed by those near public toilets (50.0%) and sewage sources (33.0%).

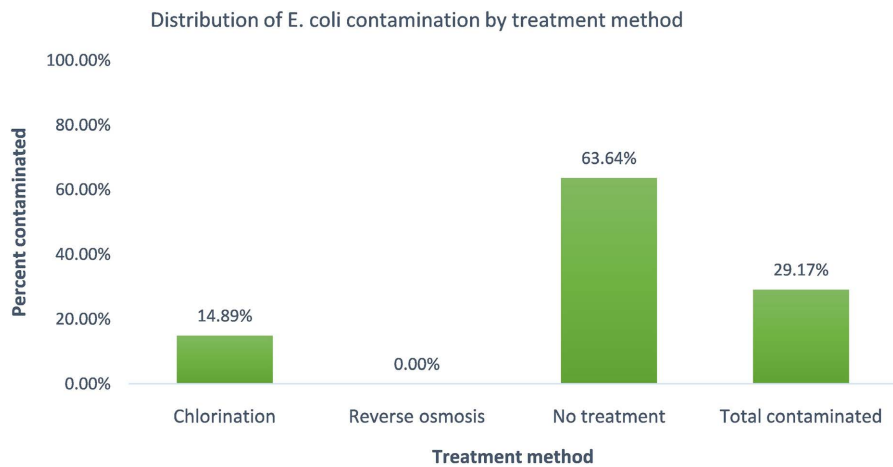
Water treatment practices also had a significant impact on *E. coli* contamination. Samples from untreated water sources had a contamination rate of 63.6%, compared to only 14.9% among chlorinated samples. These findings are illustrated in **Figures 1-3**.



**Figure 1.** Distribution of contamination by water source.



**Figure 2.** Distribution of *E. coli* contamination by pollution sources.



**Figure 3.** Distribution of *E. coli* contamination by treatment methods.

### 3.3. *E. coli* Levels in Relation to Water Source, Pollution, and Treatment Method

The Kruskal-Wallis test showed significant differences in *E. coli* contamination levels based on water source, pollution exposure and treatment method. Water source type significantly affected *E. coli* concentrations, with rain water exhibiting

the highest counts, while public supplies showed the lowest ( $p = 0.0092$ ). The source of pollution played a role, with samples associated with sewage having higher *E. coli* levels than those linked to public toilets ( $p = 0.0237$ ). Treatment methods were also influential; untreated samples had the highest bacterial concentrations, whereas chlorinated samples showed the lowest levels of *E. coli* ( $p = 0.0001$ ). While chlorination was widely used, it did not eliminate contamination entirely, suggesting challenges with dosage, contact time, or recontamination in the distribution system.

#### 4. Discussion

This study revealed a diverse mix of informal water sources in Kibera where public supply systems were predominant (72.2%), followed by boreholes (19.4%), water trucks (5.6%) and minimal use of rainwater (2.8%). The “public supply” water is largely accessed through informal vendor-managed networks, highlighting the role of both formal and informal systems in meeting residents’ water needs. This trend is consistent with other informal settlements like Mukuru and Mathare, where residents navigate inadequate infrastructure by combining different water sources [2] [8].

Chlorination (65.3%) was the most common treatment method used, aligning with practices observed in Kisumu for community-level disinfection [9]. However, the 30.6% untreated samples were concerning reflecting similar gaps in water treatment across East Africa [10]. Pollution exposure especially from sewage (50%) was a major contamination risk consistent with findings from Nairobi and South African townships linking poor sanitation and open drains to compromised water quality [2] [11]. The low use of rainwater likely reflects seasonal factors rather than an absence of harvesting practices, as rainwater harvesting is promoted as a safe alternative in other East African urban settings [12].

The study also found significant microbial contamination, with nearly one-third of samples testing positive for *E. coli* a key indicator of fecal pollution [13] [14]. The median *E. coli* count across all samples was zero indicating that more than half of the water sources met the World Health Organization and Kenyan standards for safe drinking water [4]. The presence of samples with very high contamination levels underscores intermittent but serious water quality breaches [15] [16]. The decision to use median values given the skewed data, reflects best practices in environmental microbiology [17].

Water source type played a critical role in contamination levels. The highest contamination was observed in rain and water-truck samples. Although treated through chlorination, public supplies showed high *E. coli* counts (21%), similar to other Kenyan informal settlements where illegal connections and pipe leakages contribute to contamination [8]. Boreholes, often privately managed, also had high contamination rates, highlighting the need for regulatory oversight and regular quality testing, as seen in Kisumu [9] [18]. Although all rainwater samples were contaminated, the fact that they exhibited the lowest concentration of *E. coli*

among the sources tested suggests that, with proper harvesting and storage, rain-water holds potential as a supplementary water source [12].

Pollution sources particularly sewage ( $p = 0.0237$ ) strongly influenced *E. coli* levels reinforcing the need for improved sanitation practices. The higher contamination associated with sewage reflects the direct impact of poor waste management consistent with research linking open sewers to water contamination in Nairobi slums [19]. Public toilets also contributed to contamination underscoring the need for better sanitation infrastructure [20].

Finally treatment methods significantly impacted contamination ( $p = 0.0001$ ). Untreated water had the highest bacterial loads confirming the risks of consuming water directly from the source as observed in other Kenyan slums [13] [21]. While chlorination was widely used it did not eliminate contamination entirely suggesting challenges with dosage, contact time or recontamination in the distribution system [22]. Reverse osmosis-treated water showed no contamination highlighting the potential of advanced treatment methods, though scalability and affordability remain challenges for informal settlements [23].

This study had some limitations. First, sampling was conducted during a single dry July season, which failed to capture temporal variability in pollution exposure between dry and wet seasons; thus limiting the generalizability of our findings across different seasons and environmental conditions. Monitoring programs in similar contexts recommend high-frequency sampling across key seasonal periods (e.g., both dry and wet seasons) to bracket expected variations in contaminant levels [7]. Second, the modest sample size reduces statistical power and representativeness, constraining our ability to draw broader conclusions about village-wide water quality. Future studies should incorporate multi-seasonal sampling covering dry and wet periods over multiple years and increase sample sizes to enhance temporal coverage, statistical robustness, and village-level generalizability.

## 5. Conclusion

This study demonstrates that *E. coli* contamination in Kibera's water sources is significantly influenced by the type of water source, pollution exposure and treatment method. The findings align with existing literature from Kenya and East Africa, which reports similar challenges in maintaining water safety in informal urban settlements. Addressing these issues requires a holistic approach that integrates infrastructure improvement, water quality monitoring and community based interventions tailored to the unique conditions of informal settlements.

## 6. Recommendations

- **Regular Water Quality Monitoring:** Implement monitoring for all water sources, including public supplies, boreholes, and vendor kiosks. Strengthen oversight of private water providers to ensure quality standards.
- **Infrastructure Improvements:** Upgrade the water distribution network to reduce leaks, address illegal connections, and replace aging pipes.

- **Household Water Treatment:** Promote effective water treatment methods, including boiling, chlorination, and solar disinfection. Ensure affordable access to reliable technologies.
- **Sanitation Upgrades:** Improve public toilets and waste management systems to reduce fecal contamination. Promote community-based sanitation programs.
- **Health Education:** Raise awareness about waterborne diseases and safe water handling practices through targeted education programs.
- **Further Research:** Conduct studies to evaluate the impact of interventions and explore alternative water sources and treatment technologies.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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