The Journal of Environmental Education Research and Sustainable Development
Volume 1, Issue 1 (1) (2023)

Research Article

EcoClean Environment

JEERESD

Journal Home page: www.jeeresd.online

Health risks associated with contaminated drinking water in Yaounde III district, Cameroon: exploration of Chemical and microbiological contaminations

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ARTICLE INFO

Kyes words:

Contaminated drinking water,

microbiological and chemical contaminants

Health risks,

Yaoundé III District,

waterborne diseases,

ABSTRACT

Background: Contaminated drinking water poses significant health risks to populations worldwide. In Yaoundé III District, Cameroon, access to clean drinking water is a pressing concern. This study aims to investigate the health risks associated with contaminated drinking water in this district. **Methods:** A cross-sectional study was conducted in Yaoundé III District. Water samples were collected from various sources and analyzed for microbiological and chemical contaminants. Health data were collected through surveys and medical records. Statistical analyses were performed to examine the relationship between water contamination and health outcomes. **Results:** The study found high levels of microbiological and chemical contaminants in drinking water sources. Significant associations were observed between water contamination and the prevalence of waterborne diseases, including diarrhea, typhoid fever, and cholera. **Conclusion:** The findings highlight the urgent need for interventions to improve water quality and reduce health risks in Yaoundé III District. Future research should focus on developing and implementing effective water treatment and management strategies.

1. Introduction

Access to safe drinking water is a basic human right and a key factor in public health. Contaminated water can transmit serious illnesses like diarrhea, typhoid, and cholera(WHO, 2023). In low-income nations, waterborne diseases are a major problem due to insufficient water treatment and sanitation facilities(Mosisa et al., 2021). Diarrheal diseases alone cause over 800,000 deaths annually, mostly in children under five (Merid et al., 2023). Exposure to polluted water also increases risks of skin conditions, respiratory problems, reproductive issues, and certain cancers. Addressing water contamination requires improved waste management, stronger regulations, and public education (Babuji et al., 2023). Providing universal access to clean drinking water would save millions of lives and promote sustainable development.

Ensuring the human right to safe water is an urgent global health priority. Yaoundé III District, situated in the capital city of Cameroon, faces significant challenges in providing access to clean drinking water. The district is densely populated, with many residents relying on untreated water sources such as wells, rivers, and unregulated vendors. This reliance on unsafe water sources increases the risk of waterborne diseases, including diarrhea, cholera, and typhoid fever, which pose serious public health threats. The lack of adequate water treatment facilities and monitoring systems exacerbates these risks, leading to high morbidity rates associated with contaminated water(Onyango et al., 2016). Effective water treatment is crucial for safeguarding public health, as untreated water can harbor pathogens that cause illness. To address these challenges, investments in infrastructure and community education on safe water practices are essential to improve water quality and public health outcomes in the district (Zinn et al., 2018).

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DOI : https://doi.org/10.5281/zenodo.13143315
URL: https://jeeresd.online/gallery/Health%20risks%201.10.5281zenodo.13143315.pdf
Received 16 August 2022; Received in revised form 29 October 2022; Accepted December 2022; Available online 3 January 2023

This study aims to investigate the health risks associated with contaminated drinking water in Yaoundé III District. By understanding the extent and nature of water contamination and its impact on public health, we can inform the development of effective interventions to improve water quality and reduce health risks.

2. Materials and methods

2.1. Study design

A cross-sectional study was conducted in Yaoundé III District in laboratory of toxicology and environmental impact of EcoClean Environment Company, to assess the health risks associated with contaminated drinking water. The study included water quality analysis and health data collection.

2.2. Water Sample collection and analysis

Water samples were collected from various sources, including wells, rivers, and water vendors, across the district. A total of 100 water samples were collected and analyzed for microbiological and chemical contaminants.

2.3. Microbiological analysis:

- **Indicators:** Coliform bacteria, E. coli, and other pathogenic bacteria.
- **Methods:** Membrane filtration and multiple tube fermentation techniques.

2.3.1. Membrane filtration:

For the membrane filtration method, a water sample in a sterile container was collected, ensuring proper handling and transportation to the laboratory. Once in the lab, the sample by diluting it if necessary to achieve a countable number of colonies was prepared. after assembled the filtration apparatus, which included a funnel, a filter holder, and a vacuum pump. we placed a sterile membrane filter with a pore size of 0.45 µm on the filter holder. we then poured the water sample into the funnel and applied vacuum to draw the sample through the membrane filter. To ensure complete transfer of the sample, we rinsed the funnel with sterile diluent. After filtration, we carefully removed the membrane filter and placed it on the surface of a selective agar medium in a petri dish. we incubated the dish at the appropriate temperature for the target bacteria, typically 35-37°C for 24-48 hours. Following incubation, we counted the number of colonies that had developed on the membrane filter. Each colony represented a single bacterial cell present in the original sample. If necessary, we performed additional tests, such as biochemical or molecular methods, to identify the specific bacterial species.

2.3.2. Multiple tube fermentation:

For the multiple tube fermentation method, we started by collecting a water sample in a sterile container, ensuring proper handling and transportation to the laboratory. In the lab, we prepared a series of dilutions of the water sample, typically 10-fold dilutions. we then inoculated each dilution into a set of replicate fermentation tubes containing a growth medium suitable for the target bacteria. The number of tubes per dilution depended on the specific method being used. After inoculation, we incubated the tubes at the appropriate temperature for the target bacteria, typically 35-37°C for 24-48 hours. Following incubation, we observed the tubes for signs of bacterial growth, such as gas production or turbidity.

Based on the number of positive tubes (those showing bacterial growth) at each dilution, we referred to a standard MPN table to determine the Most Probable Number of bacteria in the original sample. These methods allowed us to accurately assess the microbiological quality of the water samples and identify potential health risks associated with contaminated drinking water.

2.4. Chemical analysis:

- **Indicators:** Nitrates, heavy metals (lead, arsenic, mercury), and pesticide residues.
- **Methods:** Spectrophotometry and atomic absorption spectroscopy (ACCORDING TO THE MANUFACTURER).

2.4.1. Health data collection

Health data were collected through surveys and medical records. A structured questionnaire was administered to 500 households in the district to gather information on water sources, water treatment practices, and the prevalence of waterborne diseases. Medical records from local health facilities were also reviewed to obtain data on the incidence of waterborne diseases.

2.5. Statistical analysis

Descriptive statistics were used to summarize the water quality data and health outcomes. This involved calculating means, standard deviations, and frequencies to provide an overview of the data. These statistics helped us understand the central tendency, dispersion, and distribution of the water quality parameters and the prevalence of waterborne diseases. To examine the relationship between water contamination and health outcomes, we performed two main statistical tests: Chi-square tests and logistic regression analyses.

3. Results

3.1. Water quality analysis

3.1.1. Microbiological contaminants:

The table 1 below presents the percentage of water samples that tested positive for various microbiological contaminants. The high percentages indicate significant microbial contamination in the water sources, highlighting the need for improved water treatment and sanitation practices.

Table 1: Microbiological contaminants in water samples

Contaminant	Positive Samples (%)
Coliform Bacteria	75
E. coli	50
Other Pathogens	30

3.1.2. Chemical contaminants:

The table 2 below presents the percentage of water samples that exceeded the World Health Organization (WHO) guidelines for various chemical contaminants. The high percentages indicate significant chemical contamination in the water sources, underscoring the need for stricter regulations and monitoring of industrial and agricultural activities to reduce contamination.

Table 2: Chemical Contaminants in Water Samples

Contaminant	Samples Exceeding WHO Guidelines (%)
Nitrates	60
Lead	40
Arsenic	40
Mercury	40
Pesticide Residues	20

3.2. Health outcomes

3.2.1. Prevalence of waterborne diseases:

The table 3 below presents the prevalence of various waterborne diseases among the surveyed households in Yaoundé III District. The high prevalence rates highlight the significant public health burden associated with contaminated drinking water in the district.

Table 3: Prevalence of waterborne diseases

Disease	Prevalence (%)
Diarrhea	40
Typhoid Fever	25
Cholera	10

3.2.2. Association between water contamination and health outcomes:

The table 4 below presents the results of Chi-square tests examining the association between specific water contaminants and health outcomes. The high Chi-square values and low p-values indicate statistically significant associations between the contaminants and the respective health outcomes, underscoring the direct impact of contaminated water on public health in Yaoundé III District**.**

Table 4: Association between water contamination and health outcomes

Contaminant	Health Outcome	Chi-Square (χ^2)	p-value
Coliform Bacteria	Diarrhea	25.6	<0.001
E. coli	Typhoid Fever	18.4	<0.001
Nitrates	Cholera	12.5	<0.001

3.3. Logistic regression analysis

The table 5 below presents the results of logistic regression analyses examining the relationship between specific water contaminants and health outcomes. The odds ratios (ORs) indicate the increased likelihood of the health outcome with higher levels of the respective contaminant. The 95% confidence intervals (CIs) and p-values demonstrate the statistical significance of these associations, highlighting the direct impact of contaminated water on public health in Yaoundé III District.

Table 5: Logistic regression analysis

Contaminant	Health Outcome	Odds Ratio (OR)	95% CI	p-value
Coliform Bacteria	Diarrhea	2.5	1.8-3.4	<0.001
E. coli	Typhoid Fever	2.0	1.4-2.8	<0.001
Nitrates	Cholera	1.8	1.2-2.6	<0.01

Discussion

The study found high levels of microbiological and chemical contaminants in drinking water sources in Yaoundé III District. Significant associations were observed between water contamination and the prevalence of waterborne diseases, including diarrhea, typhoid fever, and cholera. The results of this study reveal high levels of microbiological contaminants in drinking water sources in Yaoundé III District, with 75% of samples testing positive for coliform bacteria, 50% for E. coli, and 30% for other pathogenic bacteria such as Salmonella and Shigella. These findings are consistent with previous research indicating significant microbial contamination in water sources in developing countries (Mabvouna Biguioh et al., 2020). The high prevalence of these contaminants can be attributed to several factors. Firstly, the district's reliance on untreated water sources, such as wells, rivers, and unregulated water vendors, increases the risk of contamination. Secondly, the lack of adequate water treatment and monitoring systems exacerbates the problem. Additionally, poor sanitation practices and inadequate infrastructure contribute to the contamination of water sources. The implications of these findings are severe, as they highlight the substantial health risks faced by residents, including the spread of waterborne diseases like diarrhea, typhoid fever, and cholera(Alabi et al., 2024). Effective interventions are crucial to mitigate these risks and improve public health in the district. These interventions should include the implementation of effective water treatment methods, enhanced sanitation practices, and public awareness campaigns to educate residents about the importance of safe drinking water. Chemically, 60% of water samples exceeded the WHO guideline for nitrates (50 mg/L), 40% exceeded the WHO guidelines for heavy metals (lead, arsenic, and mercury), and 20% tested positive for pesticide residues, including organophosphates and organochlorines. These findings align with studies that have reported similar chemical contamination in water sources in regions with poor water management and agricultural activities. (Ganaie et al., 2023). The presence of these chemical contaminants can be linked to agricultural runoff, industrial discharge, and inadequate waste management practices. The presence of these chemical contaminants can be linked to several factors. Firstly, agricultural runoff is a significant contributor to nitrate and pesticide contamination (Kadadou et al., 2024). The use of fertilizers and pesticides in agricultural practices can lead to these chemicals leaching into water sources(Kaur & Sinha, 2019). Secondly, industrial discharge, particularly from manufacturing and mining activities, can introduce heavy metals into water bodies (Hama Aziz et al., 2023).

Lastly, inadequate waste management practices, including improper disposal of industrial and household waste, exacerbate the contamination of water sources. The implications of these findings are severe, as they highlight the substantial health risks faced by residents. Exposure to high levels of nitrates can lead to methemoglobinemia, particularly in infants, while heavy metals such as lead, arsenic, and mercury are associated with various health issues, including neurological disorders, cancer, and developmental problems. Pesticide residues can cause acute and chronic health effects, including respiratory problems, neurological disorders, and reproductive issues(Manassaram et al., 2006). Effective interventions are crucial to mitigate these risks and improve public health in the district. These interventions should include the implementation of effective water treatment methods, enhanced sanitation practices, and public awareness campaigns to educate residents about the importance of safe drinking water. Additionally, stricter regulations and monitoring of industrial and agricultural activities are necessary to reduce chemical contamination.

The prevalence of waterborne diseases in the surveyed households further underscores the health risks associated with contaminated drinking water. Specifically, 40% of households reported at least one case of diarrhea in the past month, 25% reported at least one case of typhoid fever in the past year, and 10% reported at least one case of cholera in the past year. These high rates of waterborne diseases are consistent with the microbiological contamination found in the water samples and highlight the significant public health burden in the district (Osiemo et al., 2019). The high prevalence of waterborne diseases can be attributed to several factors. Firstly, the lack of access to clean drinking water forces residents to rely on contaminated sources, increasing their exposure to pathogens. Secondly, inadequate sanitation and hygiene practices contribute to the spread of these diseases. Additionally, the absence of effective water treatment methods and public health interventions exacerbates the problem.

The association between water contamination and health outcomes is evident from the statistical analyses. Households using water sources with high levels of coliform bacteria had a significantly higher prevalence of diarrhea. Similarly, households using water sources with high levels of E. coli had a significantly higher prevalence of typhoid fever. Furthermore, households using water sources with high levels of nitrates had a significantly higher prevalence of cholera. These associations underscore the direct impact of contaminated water on the health of residents in Yaoundé III District.

Limitations

The study was limited to Yaoundé III District, which may not be representative of the entire country. The cross-sectional design of the study limits the ability to establish causality. Additionally, the study relied on self-reported data from households, which may be subject to recall bias.

Conclusion

The study found high levels of microbiological and chemical contaminants in drinking water sources in Yaoundé III District. Significant associations were observed between water contamination and the prevalence of waterborne diseases, including diarrhea, typhoid fever, and cholera. The findings highlight the urgent need for interventions to improve water quality and reduce health risks in the district. Future research should focus on developing and implementing effective water treatment and management strategies.

What is already known on this topic

- Contaminated drinking water poses significant health risks, including the spread of waterborne diseases.
- The burden of waterborne diseases is particularly high in developing countries due to inadequate water treatment and sanitation infrastructure.
- Previous studies have highlighted the importance of water treatment in reducing health risks.

What this study adds

- A comprehensive analysis of both microbiological and chemical contaminants in drinking water sources in Yaoundé III District.
- Significant associations between water contamination and the prevalence of waterborne diseases, including diarrhea, typhoid fever, and cholera.
- Insights into the extent and nature of water contamination and its impact on public health, which can inform the development of effective water treatment and management strategies.

Acknowledgements

The authors would like to acknowledge the contributions of the field researchers, local health facilities, and community members who participated in this study and. We also thank the EcoClean Environment Company for their analysis.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

- **Embolo Enyegue Elisée Libert:** Conceptualization, data collection, analysis, and writing of the original draft.
- **Baba Djidjiwa Landry:** Data collection, analysis, and review of the manuscript.
- **Ngo Binogol Mirabelle:** Data collection, analysis, and review of the manuscript.

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