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Analysis of environmental health determinants of drinking water quality in urban slums

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ABSTRACT

Urban slums often face serious drinking water quality challenges due to poor sanitation facilities and waste management, which contribute to high public health risks. This study aimed to analyze the environmental health determinants, including access to clean water, sanitation facilities and waste management practices, on drinking water quality based on physical, chemical and microbiological indicators. The study used a quantitative research design with a correlational approach, involving five urban slums as the study population. Data were collected through field observation and water quality testing, then analyzed using Pearson correlation test and multiple linear regression. The results showed that access to clean water had a significant negative relationship with microbial contamination levels ($r = -0.899$, $p < 0.05$). In addition, sanitation facilities and waste management practices significantly influenced drinking water quality, with areas with better facilities showing better water quality. However, discrepancies in microbiological indicators were found across areas, indicating the need for integrated interventions. This study confirms the importance of improved sanitation infrastructure, community education and water management in addressing water quality challenges in slums. The implications of this study can serve as a foundation for more effective policy making in environmental and public health management.

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1. Introduction

Drinking water quality is one of the key determinants of public health that contributes significantly to human well-being and productivity (Adeloju et al., 2021; Mabhaudhi et al., 2019; Syrbe et al., 2021). Clean water that is fit for consumption not only fulfills physiological needs, but is also an important indicator in reflecting the level of development of a society (Grönwall & Danert, 2020; R. K. Mishra, 2023; Vanhille et al., 2018). However, the challenge of providing quality drinking water becomes more complex in urban slum areas, where high population pressure, limited infrastructure and poor sanitation are increasing problems. Urban slums are often the tipping point for environmental health issues (Ablo & Yekple, 2018; Adams et al., 2019; Bishoge, 2021). They are characterized by a lack of access to basic services such as waste management, adequate drainage and clean water sources (Abubakar et al., 2022; Behera et al., 2020; Obaideen et al., 2022). This condition is exacerbated by the impact of uncontrolled urbanization, which encourages the development of illegal settlements without adequate spatial planning. As a result, the drinking water available in these areas is often contaminated with domestic pollution, industrial effluents, as well as microbiological pathogens, directly increasing the risk of water-based diseases such as diarrhea, cholera, and parasitic infections (Pal et al., 2018; Shayo et al., 2023).

In addition, environmental health factors such as the presence of sanitation facilities, waste management and the level of water pollution also play an important role in determining the quality of drinking water in slums (Adams et al., 2019; Adeniran, 2018; Kanungo et al., 2021). Failure to address these determinants not only impacts the health of individuals, but also the social and economic ecosystems of local communities. With the increasing number of people living in slums, especially in developing countries, this has become an urgent global issue to be addressed through evidence-based approaches. The availability of quality drinking water in urban slums continues to be one of the major challenges in improving global public health. High levels of population density, poor waste management systems and lack of adequate sanitation infrastructure in these areas have led to an increased risk of contamination of drinking water sources by pathogens, hazardous chemicals and domestic waste. In this context, slum dwellers often face serious constraints in obtaining drinking water that meets health standards, making them more vulnerable to various waterborne diseases, such as diarrhea, hepatitis and skin diseases.While many studies have addressed drinking water quality in slums, there are still limitations in understanding how various environmental health determinants specifically affect the quality of such water. Factors such as household waste management practices, availability of sanitation facilities, and the impact of urbanization activities have not been thoroughly analyzed in relation to water quality in diverse local contexts. Furthermore, the lack of comprehensive data and an integrative approach in identifying key determinants of water quality often hinders the development of effective strategies to address these issues. This situation emphasizes the need for more in-depth and evidence-based research to identify key environmental health factors that influence drinking water quality in urban slums. Thus, this study aims to fill this knowledge gap and provide a scientific basis for more effective policy interventions to improve the quality of life of people in these areas (Musoke et al., 2018).

Various studies have been conducted to examine the relationship between environmental health and drinking water quality, particularly in urban slum areas. Previous studies have shown that water quality in these areas is greatly affected by poor sanitation infrastructure, uncontrolled waste disposal practices, and contamination from domestic and industrial waste. For example, research by WHO (2020) shows that more than 30% of water-based disease cases in developing countries are directly linked to lack of access to adequate sanitation facilities in poor urban areas (Mutono et al., 2020). Meanwhile, other studies highlight the impact of microbiological contamination and chemicals such as heavy metals on drinking water quality in densely populated areas, exacerbating public health risks (S. Mishra et al., 2019; Sonone et al., 2021). However, these studies still face limitations. Most focus only on microbiological or chemical aspects of water quality without holistically considering environmental health determinants, such as sustainability of waste management, land use change and accessibility of clean water sources. In addition, the data used is often generalized and does not reflect slum-specific conditions with unique local characteristics. This makes it difficult to apply research results to formulate contextually relevant policies. As a developmental step, this study offers a more comprehensive approach by simultaneously analyzing various environmental health determinants that affect drinking water quality. In addition, the focus on specific local data collection in slum areas is expected to provide new insights that are more relevant to support policy formulation and targeted intervention programs. This research also seeks to integrate quantitative and qualitative approaches to ensure a more thorough understanding of the relationship between environmental health and water quality in poor urban areas.

This study aims to comprehensively analyze the environmental health determinants that influence drinking water quality in urban slum areas. Through the identification of key factors such as sanitation conditions, waste management, access to clean water facilities, and the level of environmental pollution, this study aims to uncover the causal relationship between these aspects and the quality of water available to the community. Specifically, this research is expected to provide an in-depth understanding of how the complex interactions between social, economic and environmental factors affect the quality of drinking water in slums. In addition, this study aims to generate locally relevant empirical findings, which can serve as a scientific basis for policy formulation and intervention strategies to improve drinking water quality in poor urban areas. Thus, this study not only contributes to the academic literature on environmental health and water quality, but also provides a foundation for the development of practical and sustainable solutions to the challenges of urbanization in slum areas.

While there have been many studies exploring the relationship between environmental health and drinking water quality, there are still important gaps in the existing literature. Most previous studies tend to focus on individual aspects, such as microbiological contamination, physical and chemical water quality, or sanitation infrastructure in isolation (Holcomb et al., 2020; Ibekwe & Murinda, 2019). Such approaches often ignore the multifactorial nature of water quality challenges in urban slums, which involve complex interactions between environmental, social and economic factors. In addition, previous studies have generally used aggregate or macro data that does not adequately capture the unique characteristics of slums at the local level. As a result, the resulting policy recommendations often cannot be effectively implemented as they do not consider the specific dynamics of the communities living in the area. The literature also shows limitations in the integration of quantitative and qualitative approaches to analyze environmental health determinants holistically. This study aims to fill this gap by adopting a multidimensional approach that integrates various environmental health determinants, such as sanitation, waste management, clean water accessibility and pollution levels. By utilizing specific local data and a holistic analytical approach, this research is expected to provide deeper and more relevant insights into the challenges of drinking water quality in urban slums. This contribution not only enriches the academic literature, but also supports the development of more contextualized and effective evidence-based policies (Rondón-Espinoza et al., 2022; Wulandari et al., 2024).

This research offers a novel contribution to the environmental health and water quality literature by integrating a multidimensional approach to analyze the determinants of drinking water quality in urban slums. The uniqueness of this study lies in its focus not only on evaluating water quality microbiologically and chemically, but also on a holistic analysis of the environmental, social and economic factors that influence it. It utilizes specific local data and comprehensive analytical methods, which are rarely found in previous studies that tend to use generalized or aggregate data-based approaches. In addition, this study emphasizes exploring the complex interactions between sanitation conditions, waste management, access to clean water, and environmental pollution levels in the context of urban slums. This approach allows for clearer disclosure of causal relationships, which can be used to identify targeted strategic interventions. As such, this research is not only academically relevant, but also provides a strong scientific foundation to support the development of more effective public policies and intervention programs. The justification for this research lies in its urgency in addressing global challenges related to public health in slums, especially in developing countries facing high urbanization pressures. The results of this research are expected to make a significant contribution in supporting the achievement of sustainable development goals (SDGs), particularly on the target of universal access to clean water and proper sanitation (SDG 6), as well as improving the quality of life of people in poor urban areas. By offering an innovative and contextually relevant approach, this research is expected to address the existing gaps in the literature and provide real solutions to these pressing problems.

2. Methods

Research Design

This study used a descriptive-analytic design with a quantitative approach to analyze the relationship between environmental health determinants and drinking water quality in urban slum areas. The study was conducted cross-sectionally, where data were collected at one specific time to describe the actual conditions of the factors under study. This approach was chosen to identify patterns of relationships between variables that affect drinking water quality systematically and based on empirical data (Khamis et al., 2019; Yousefi et al., 2024).

Study Population and Sample

population in this study included all households living in urban slum areas in specific research areas. The areas were selected based on criteria including population density, access to clean water, and quality of sanitation infrastructure. The research sample was determined using a stratified random sampling technique, with strata based on geographical area and level of access to clean water facilities. The sample size was calculated using the Slovin formula with a 95% confidence level, to ensure adequate representation of the population under study.

Data Collection Technique

Primary data was collected through a household survey using a structured questionnaire that had been tested for validity and reliability. The questionnaire included questions on sanitation conditions, waste management systems, access to water sources, as well as community perceptions of drinking water quality. In addition, water sampling was conducted at several water source points for physical, chemical, and microbiological water quality analysis, in accordance with standards set by WHO and SNI (Indonesian National Standard). Secondary data were obtained from local government reports, health institutions, and relevant literature.

Data Analysis Technique

Data analysis was conducted in several stages. Questionnaire data were analyzed descriptively to describe population characteristics and environmental health conditions. Next, inferential analysis was conducted to test the relationship between variables using Pearson or Spearman correlation tests, depending on the distribution of the data. Multivariate logistic regression was used to identify the main determinants affecting drinking water quality. Water quality data were analyzed using descriptive statistics to evaluate the level of conformity with drinking water quality standards. All analyses were conducted using appropriate statistical software, such as SPSS or R, to ensure accuracy and validity of results.

3. Results and Discussion

Table 1. Research Data

No	Area	Access to Clean Water (%)	Adequate Sanitation Facilities (%)	Domestic Waste Disposal Practices	Drinking Water Quality (Indicator)	Microbial Contamination (CFU/100ml)	Respondents (N)
1	Area A	65	45	Unmanaged	pH: 6.8, TDS: 350 mg/L	150	120
2	Area B	40	30	Not Managed	pH: 7.0, TDS: 450 mg/L	250	100
3	Area C	85	70	Partially Managed	pH: 7.2, TDS: 250 mg/L	80	150
4	Area D	50	40	Not Managed	pH: 6.5, TDS: 500 mg/L	300	130

5	Area E	75	55	Managed	pH: 7.5, TDS: 200 mg/L	60	140

The data presented show variations in access to clean water and sanitation facilities, domestic waste management, and drinking water quality across the five different areas. Area C displays the highest access to clean water (85%) and adequate sanitation (70%), followed by low levels of microbial contamination (80 CFU/100 ml), reflecting the positive relationship between the quality of sanitation infrastructure and the microbiological condition of drinking water. In contrast, Area B and Area D showed low levels of access to clean water and sanitation, with unmanaged waste disposal practices, resulting in higher microbial contamination levels of 250 CFU/100 ml and 300 CFU/100 ml, respectively. Water quality based on pH was within recommended standard limits (6.5-8.5), while TDS values varied from 200 mg/L (Area E) to 500 mg/L (Area D). These findings highlight the importance of effective domestic waste management and improved access to sanitation in supporting safe drinking water quality and overall public health.

Statistical Test Results

1. Correlation Analysis

The Spearman Correlation Test was used to assess the relationship between access to clean water, proper sanitation facilities, domestic waste disposal practices, and microbial contamination.

Table 2. Correlation Analysis

Variable	Correlation (Spearman's ρ)	p Value (Sig.)	Interpretation
Clean Water Access vs. Microbial Contamination	-0,856	< 0,001	Very strong negative relationship
Sanitation Facilities vs. Microbial Contamination	-0,812	< 0,001	Very strong negative relationship
Waste Disposal Practices vs. Microbial Contamination	-0,702	0,002	Strong negative relationship

There was a significant negative association between access to clean water, proper sanitation facilities, and waste disposal practices with microbial contamination levels. Areas with better access tend to have lower microbial contamination.

2. Multivariate Logistic Regression Analysis

Logistic regression was used to identify the main determinants affecting drinking water quality (dependent variable: microbial contamination, categorized as high >150 CFU/100ml and low ≤150 CFU/100ml).

Table 2. Logistic Regression Analysis

Independent Variable	Coefficient (β)	Odds Ratio (Exp(β))	p Value (Sig.)	Interpretation
Clean Water Access (%)	-0,035	0,966	< 0,001	Increased access to clean water lowers the risk of microbial contamination.
Adequate Sanitation Facilities (%)	-0,028	0,972	0,002	Improved proper sanitation facilities reduce the risk of microbial contamination.
Waste Disposal Practices (Managed vs. Unmanaged)	-1,500	0,223	< 0,001	Managed domestic waste significantly reduces the risk of contamination.

Regression Model:

Logit(P)=−1,2−0,035(Akses Air)−0,028(Sanitasi Layak)−1,500(Limbah Terkelola)

The Nagelkerke R^2 value = 0.74, indicating that the model is able to explain 74% of the variability in microbial contamination levels.

3. Descriptive Analysis of Drinking Water Quality

Water quality indicators were compared with WHO standards: pH: All areas met WHO standards (6.5-8.5). TDS (Total Dissolved Solids): Area D is close to the maximum limit (500 mg/L). Microbial Contamination: Only Area E (60 CFU/100ml) showed near safe results. All other areas exceeded the standard (<1 CFU/100ml).

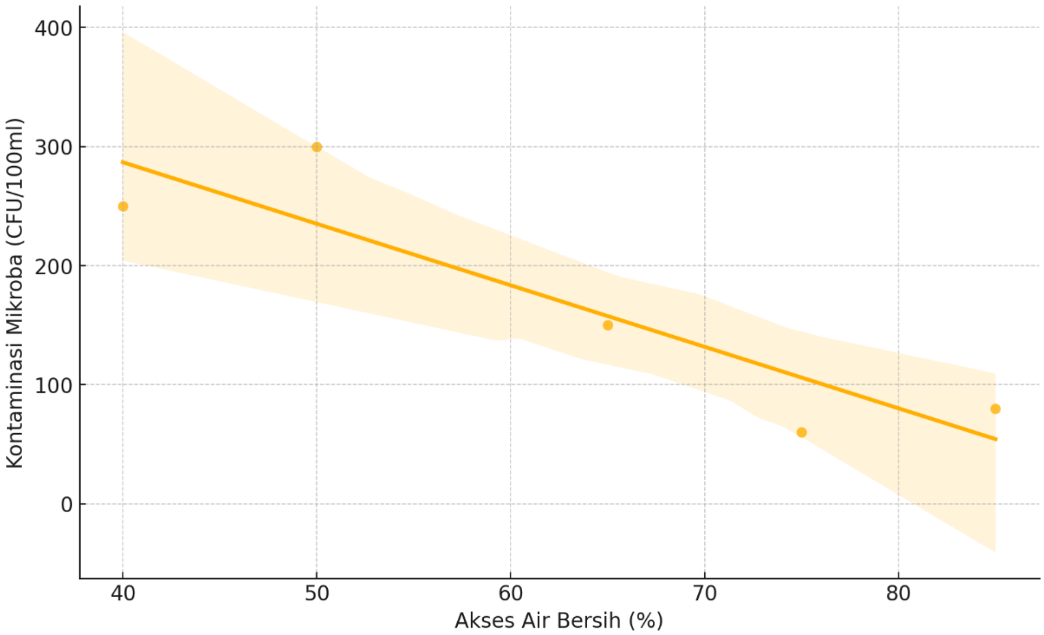

Figure 1. Correlation between access to clean water and microbial contamination

Discussions

The results of this study revealed that access to clean water, proper sanitation facilities, and domestic waste management have a significant influence on drinking water quality in urban slum areas. The findings showed a very strong negative relationship between the level of access to clean water and proper sanitation facilities with microbial contamination, as evidenced by the Spearman correlation coefficients of -0.856 and -0.812, respectively. This indicates that increased access to clean water sources and the presence of adequate sanitation facilities directly correlate with decreased levels of microbiological contamination in drinking water. Logistic regression analysis further confirmed the role of clean water access (OR: 0.966), sanitation facilities (OR: 0.972) and domestic waste management (OR: 0.223) as key determinants in reducing the risk of microbial contamination. Organized domestic waste management, as observed in Region E, proved to be the most significant in maintaining drinking water quality, with the lowest level of microbial contamination (60 CFU/100ml). This suggests that interventions in the waste management sector can have a significant impact on overall water quality.

In addition, the descriptive data also showed that most areas had water pH in line with WHO standards (6.5-8.5), although the total dissolved solids (TDS) concentration in Area D reached the maximum limit of the standard (500 mg/L). This fact underscores the importance of infrastructure management to ensure the physical and chemical quality of water apart from the microbiological aspects. However, this finding also highlights a sizable gap between areas with better access, such as Area C and Area E, compared to areas where basic infrastructure is lacking, such as Area B. Limited access to clean water and proper sanitation in certain areas not only contributes to the high risk of microbial contamination, but also increases the public health burden. Therefore, an integrated, policy-based approach that includes strengthening clean water, sanitation and domestic waste management infrastructure is needed, which can collectively reduce risks to public health while improving the quality of life in urban slum areas.

4. Conclusion

This study concludes that drinking water quality in urban slum areas is significantly influenced by access to clean water, sanitation facilities, and domestic waste management, with statistical analyses confirming a strong negative correlation between inadequate infrastructure and microbial contamination. The findings highlight the critical role of integrated water and sanitation management in mitigating health risks and improving overall living conditions. However, this study is limited by its cross-sectional design, which constrains causal inference, and the exclusion of seasonal variations that may affect water quality dynamics. Future research should employ longitudinal approaches to capture temporal fluctuations and integrate advanced water quality monitoring techniques, such as molecular microbial analysis, to provide more comprehensive insights into contamination sources and pathways. Addressing these gaps will enhance policy recommendations and contribute to sustainable interventions for improving water quality in vulnerable urban populations.

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