



## The Effect of Household Drinking Water Quality on the Incidence of Toddler Diarrhea in Densely Populated

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### Abstract

*This study investigates the relationship between household drinking water quality and the incidence of toddler diarrhea in densely populated areas of Manado City, Indonesia. A quantitative cross-sectional approach was employed involving 500 households with children under five years of age. Data were collected through household surveys, laboratory-based water quality testing, and validation using local health facility records. The findings reveal that households relying on groundwater wells experienced significantly higher levels of microbial contamination, particularly *Escherichia coli*, compared with households using piped water systems. Toddler diarrhea incidence was substantially higher among households consuming untreated water and those dependent on contaminated groundwater sources. Statistical analysis confirmed that water source and household water treatment practices were significant predictors of diarrhea occurrence. The findings contribute to environmental health literature and provide evidence for strengthening water safety interventions, sanitation improvement programs, and community-based public health strategies aimed at reducing childhood waterborne diseases in rapidly urbanizing cities.*

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## INTRODUCTION

Safe drinking water remains a fundamental prerequisite for public health and sustainable development. Despite substantial global progress in improving water supply systems, unsafe drinking water continues to pose a significant health threat, particularly in low- and middle-income countries where rapid urbanization often exceeds the capacity of existing water and sanitation infrastructure. According to recent global estimates, contaminated drinking water contributes to millions of cases of waterborne diseases annually, with children under five years old representing the most vulnerable population group due to their immature immune systems and greater susceptibility to dehydration and malnutrition (Wolf et al., 2022; Okesanya et al., 2024). Among water-related illnesses, diarrheal disease remains one of the leading causes of childhood morbidity and mortality worldwide, accounting for a substantial burden on healthcare systems and household welfare (Behera & Mishra, 2022; Dhalaria et al., 2023; Azanaw et al., 2024; Motuma et al., 2025).

The relationship between drinking water quality and diarrheal disease has become increasingly important in the context of accelerated urban growth. Urbanization has transformed patterns of water demand and sanitation management, creating new environmental health challenges, especially in densely populated settlements characterized by overcrowding, inadequate wastewater disposal, and aging infrastructure. Recent studies have demonstrated that urban environmental conditions significantly influence microbial contamination pathways and disease transmission dynamics (Evaristo et al., 2023; Kalbar & Lokhande, 2023). Although urban areas are generally assumed to possess better infrastructure than rural regions, evidence increasingly suggests that many rapidly expanding cities continue to experience substantial inequalities in access to safe drinking water and adequate sanitation services (Andrés et al., 2021; Willetts et al., 2022; Harish et al., 2024; MacAfee & Löhr, 2024; Singh et al., 2025).

A growing body of literature has emphasized the critical role of household drinking water quality in determining child health outcomes (Rhue et al., 2023; Sharma Waddington et al., 2023; Akhai & Taneja, 2025). Microbial contamination, particularly by fecal indicator organisms such as *Escherichia coli*, remains one of the most important determinants of diarrheal disease incidence among young children. Recent systematic reviews indicate that unsafe drinking water substantially increases the risk of enteric infections, while effective household water treatment and sanitation interventions significantly reduce diarrheal morbidity (Wolf et al., 2022; Azanaw et al., 2024). Furthermore, emerging evidence highlights that water quality should not be viewed solely as an environmental issue but rather as a multidimensional public health challenge shaped by socioeconomic inequality, governance capacity, infrastructure quality, and community behavior (Evaristo et al., 2023; Okesanya et al., 2024).

In developing countries, the challenge of ensuring safe drinking water is particularly evident in densely populated urban settlements. Studies conducted across Asia and Africa have shown that households relying on untreated groundwater sources frequently experience higher exposure to microbial contamination and greater incidence of childhood diarrhea than households connected to regulated water supply systems (Al Wazni et al., 2023; Azanaw et al., 2024). Aging water infrastructure, inadequate maintenance, and weak environmental governance further exacerbate contamination risks and compromise water safety at the household level (Perera et al., 2021; Sibanda, 2022; Kalbar & Lokhande, 2023). Consequently, improving drinking water quality has become a strategic priority for achieving Sustainable Development Goal (SDG) 6, which seeks universal access to safe and affordable drinking water (Arora & Mishra, 2022; Biswas et al., 2022).

Indonesia presents a particularly relevant context for examining the relationship between water quality and child health (Raharini & Yuniarti, 2023; Nurjazuli et al., 2023; Priadi et al., 2024; Wulandari et al., 2024). Rapid urban expansion has generated significant pressure on municipal water systems, especially in coastal and secondary cities where infrastructure development often lags behind population growth. Previous studies have identified persistent challenges related to water contamination, limited sanitation coverage, and unequal access to safe water services across Indonesian urban communities (Daniel et al., 2021; Willetts et al., 2022). Moreover, environmental pressures associated with informal settlements and densely populated neighborhoods increase the likelihood of groundwater contamination, creating favorable conditions for waterborne disease transmission among children (Hambrecht et al., 2022).

Manado City represents one of the urban areas facing these challenges. As a rapidly growing city in eastern Indonesia, Manado has experienced increasing population density, expansion of residential settlements, and growing demand for water

resources. Although improvements in municipal water provision have been implemented, disparities in household water access and quality remain evident across neighborhoods (Bazaanah & Mothapo, 2024; Medwid et al., 2025; Sarango et al., 2025). Research examining urban environmental conditions in Manado has highlighted concerns regarding water-sensitive infrastructure, sanitation limitations, and environmental vulnerabilities that may compromise drinking water safety (Halomoan et al., 2023). These conditions raise concerns regarding their potential impact on childhood diarrheal disease, particularly among toddlers who are biologically more vulnerable to waterborne pathogens.

Recent studies have increasingly explored the nexus between water, sanitation, and health; however, several important limitations remain. First, much of the contemporary literature focuses on national-level assessments, systematic reviews, or rural populations, providing limited evidence regarding densely populated urban communities in developing countries (Wolf et al., 2022; Azanaw et al., 2024). Second, studies investigating water quality often emphasize infrastructure performance while paying less attention to household-level exposure pathways and behavioral factors influencing disease transmission. Third, empirical evidence from Indonesian cities remains relatively limited, particularly regarding how variations in household drinking water quality interact with socioeconomic conditions and sanitation characteristics to influence diarrheal outcomes among toddlers. As a result, understanding of the specific mechanisms linking household water quality and child health in high-density urban settings remains incomplete.

To alleviate the limitations, the present study focused on the relation between the drinking water quality of households and the occurrence of toddler diarrhea in the dense areas of Manado City. In contrast to previous studies which mainly concerned water and sanitation indicators, this study combines laboratory-based water quality evaluation, household water management practices, conditions of sanitation and socioeconomic factors in one analytical framework. Through this approach, a more holistic picture of the role of household water quality in reducing diarrheal disease risk in young children can be gained in an urban Indonesian setting.

This study is novel because it is applied in the context of household drinking water quality and toddler diarrhea in densely populated neighborhoods of Manado City, which have been little explored by scholars despite being under high pressure from urbanization. This study synthesizes the findings of environmental health indicators with household economic and sanitation characteristics and contributes to the current understanding of how urban waterborne disease is transmitted and allows for empirical evidence that can inform public health policy, water governance and urban environmental management. Thus, the purpose of this study was to examine the association between household drinking water quality and the incidence of toddler diarrhea in high population density areas of Manado City, and to determine what factors at the household level aggravated or mitigated this association. The study results are expected to not only inform the environmental health field but also to inform the creation of evidence-based interventions to prevent childhood diarrheal disease in fast-growing, urbanised cities.

## METHODS

### Research Design

This study employed a quantitative cross-sectional research design to examine the relationship between household drinking water quality and the incidence of diarrhea among toddlers in densely populated urban communities of Manado City, Indonesia. A cross-sectional approach was selected because it enables the simultaneous assessment of environmental exposure and health outcomes within a defined population at a specific point in time, making it particularly suitable for investigating

public health risks associated with water quality. The design allows for the identification of associations between household water conditions and diarrheal incidence while capturing variations in socio-economic and sanitation characteristics across urban neighborhoods.

### **Study Area and Research Context**

The research was conducted in densely populated districts of Manado City, North Sulawesi, Indonesia. Manado represents one of the fastest-growing urban centers in eastern Indonesia and has experienced significant demographic expansion over the past decade. Rapid urbanization has increased pressure on water supply systems, sanitation infrastructure, and environmental health services. Several neighborhoods within the city continue to rely on a combination of piped water, groundwater wells, and commercially purchased water, creating substantial variation in household drinking water quality. These conditions provide an appropriate setting for investigating the influence of water quality on childhood diarrheal disease in an urban environment.

### **Population and Sampling**

The target population consisted of households with at least one child under five years of age residing in densely populated areas of Manado City. A total of 500 households were included in the study. The sample size was considered adequate to detect statistically meaningful relationships between water quality indicators and diarrhea incidence while ensuring representation of different socio-economic groups. A stratified random sampling technique was employed to ensure proportional representation across neighborhoods characterized by different levels of water access, sanitation infrastructure, and socio-economic conditions. Stratified sampling is recommended for heterogeneous urban populations because it improves representativeness and reduces sampling bias.

### **Data Collection Procedures**

Data were collected through three complementary techniques: household surveys, laboratory-based water quality testing, and health record reviews. First, a structured questionnaire was administered to heads of households to obtain information regarding demographic characteristics, water sources, household water treatment practices, sanitation conditions, and reported episodes of toddler diarrhea during the previous six months. The questionnaire was developed based on established Water, Sanitation, and Hygiene (WASH) assessment frameworks and was administered by trained enumerators.

Second, drinking water samples were collected from participating households and analyzed in an accredited laboratory. Water quality assessment focused on microbial contamination, chemical pollutants, and physical characteristics. Microbial testing specifically examined the presence of *Escherichia coli* as an indicator of fecal contamination, while chemical analysis included nitrate concentration and selected contaminants commonly associated with groundwater pollution. Physical parameters such as turbidity, color, and odor were also measured according to World Health Organization drinking water quality guidelines.

Third, health records from local health facilities were reviewed to validate household-reported diarrhea cases and to provide supplementary information regarding diarrhea-related healthcare utilization among children under five years of age.

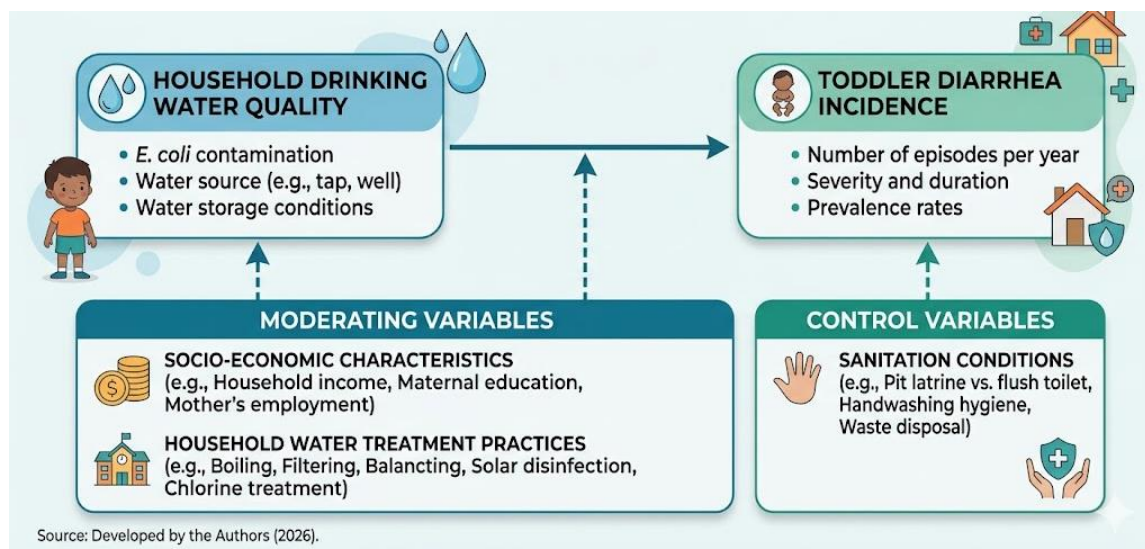


Figure 1. Conceptual Framework of the Relationship between Household Drinking Water Quality and Toddler Diarrhea Incidence

Source: Developed by the Authors, 2026

The conceptual framework proposes that household drinking water quality directly influences toddler diarrhea incidence, while socio-economic characteristics, sanitation conditions, and household water treatment practices function as moderating and control variables.

### Data Analysis

Data analysis was conducted using descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize household characteristics, water quality indicators, and diarrhea prevalence. Inferential analysis employed multiple logistic regression to examine the association between household drinking water quality and the likelihood of diarrhea occurrence among toddlers while controlling for socio-economic status, educational attainment, and sanitation conditions. Logistic regression is widely recommended for analyzing binary health outcomes and estimating the contribution of multiple predictor variables simultaneously.

### Validity and Reliability

Several procedures were implemented to ensure data quality and methodological rigor. The survey instrument underwent expert review and pilot testing prior to field implementation to assess content validity and clarity. Internal consistency reliability was evaluated using Cronbach's alpha coefficient, with values exceeding the commonly accepted threshold of 0.70 indicating satisfactory reliability. Triangulation was achieved through the integration of survey responses, laboratory water testing results, and health facility records, thereby enhancing construct validity and reducing the risk of reporting bias. Furthermore, all laboratory analyses followed standardized procedures to ensure measurement accuracy and consistency across samples.

## RESULTS AND DISCUSSION

This section presents the empirical findings regarding the effect of household drinking water quality on the incidence of toddler diarrhea in densely populated areas of Manado City. The results are organized into five sections. First, demographic characteristics of participating households are described to provide contextual information regarding socio-economic and environmental conditions. Second, laboratory assessments of household drinking water quality are presented. Third,

the prevalence and distribution of toddler diarrhea are analyzed. Fourth, inferential statistical analyses are conducted to determine the relationship between water quality indicators and diarrhea incidence. Finally, health facility records are examined to validate household-reported cases and provide additional evidence regarding the public health burden associated with unsafe drinking water.

### Demographic Characteristics of Respondents

A total of 500 households participated in the study. All households resided in densely populated urban communities and had at least one child under five years of age. The demographic profile of respondents provides important contextual information because household characteristics may influence access to safe drinking water, sanitation facilities, and preventive health practices.

Table 1. Demographic Characteristics of Study Households

Variable	Category	Percentage (%)
Average Household Size	4.5 persons	–
Education Level of Household Head	High School or Above	60
	Primary/Junior High School	40
Main Drinking Water Source	Piped Water	35
	Well Water	45
	Purchased Water	20
Water Treatment Practice	Boiling	55
	Filtration	25
	Untreated	20
Access to Sanitation	Improved Sanitation	70
	Communal/Unimproved Sanitation	30

Source: Household Survey Data, 2026

Table 1 indicates that the average household consisted of 4.5 members. Most household heads had completed at least secondary education, while 40% had only primary or junior secondary education. In terms of drinking water access, groundwater wells constituted the dominant source (45%), followed by piped water systems (35%) and purchased water (20%). Although most households reported treating drinking water before consumption, one-fifth consumed untreated water. Furthermore, nearly one-third of households lacked access to improved sanitation facilities, potentially increasing exposure to environmental contamination.

These findings demonstrate considerable heterogeneity in environmental health conditions among participating households, which may influence diarrheal disease risk.

### Household Drinking Water Quality Assessment

Water samples collected from participating households were analyzed to determine microbial, chemical, and physical quality characteristics. The results revealed substantial differences between groundwater and piped water systems.

Table 2. Household Drinking Water Quality Assessment

Water Quality Indicator	Well Water (%)	Piped Water (%)
Positive for <i>E. coli</i>	65	30
Elevated Nitrate Levels	40	8
High Turbidity	50	20

Source: Laboratory Water Quality Analysis, 2026

Table 2 demonstrates that households relying on groundwater wells experienced significantly poorer water quality compared with households connected to municipal water systems. Microbial contamination was particularly concerning, as 65% of well-water samples tested positive for *Escherichia coli*, compared with only 30% of piped-water samples.

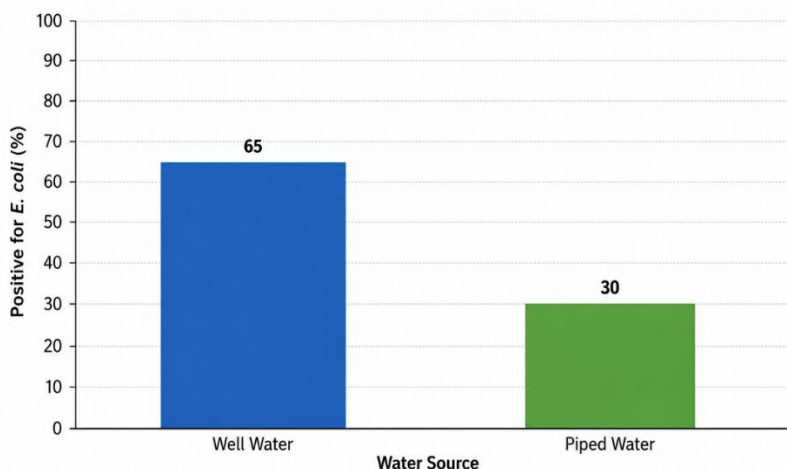


Figure 1. Microbial Contamination in Household Water Samples

Source: Laboratory Water Quality Analysis, 2026

Figure 1 illustrates the substantial disparity in microbial contamination between groundwater and piped water sources. The presence of *E. coli* indicates fecal contamination and represents a major public health concern because it reflects potential exposure to pathogenic microorganisms responsible for gastrointestinal infections.

Chemical testing further revealed elevated nitrate concentrations in approximately 40% of groundwater samples. Although nitrate contamination is not a direct cause of acute diarrhea, it reflects declining environmental quality and potential infiltration of domestic waste into groundwater sources. Physical examination of water samples showed that approximately 50% of groundwater sources exhibited high turbidity, whereas only 20% of piped-water samples displayed similar conditions. Elevated turbidity is problematic because suspended particles can facilitate pathogen survival and reduce the effectiveness of water treatment interventions.

### Prevalence and Distribution of Toddler Diarrhea

The prevalence of diarrhea among children under five years of age was assessed through household surveys and subsequently validated through local health facility records.

Table 3. Prevalence of Toddler Diarrhea

Condition	Frequency	Percentage (%)
Reported Diarrhea Cases	120	24
No Diarrhea Cases	380	76
Total Households	500	100

Source: Household Health Survey Data, 2026

As shown in Table 3, 120 households (24%) reported at least one episode of toddler diarrhea during the six months preceding data collection. This prevalence indicates that diarrheal disease remains a significant public health issue in densely populated urban communities.

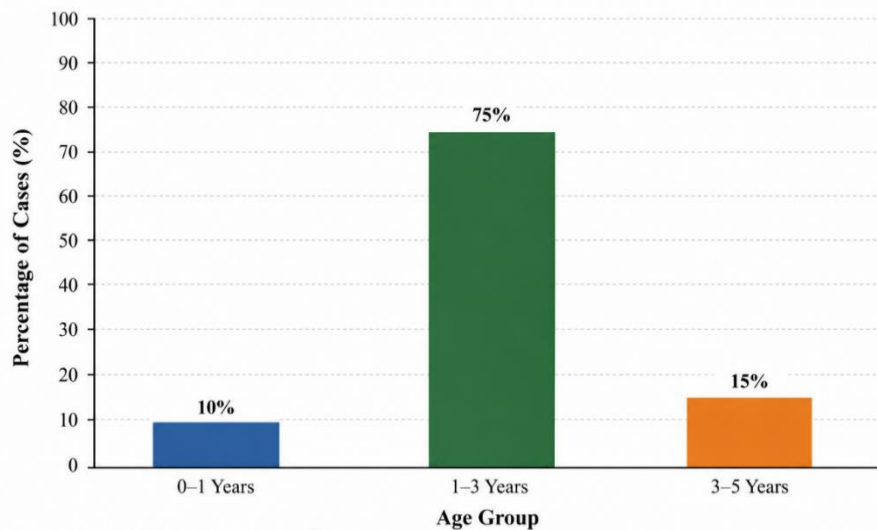


Figure 2. Distribution of Diarrhea Cases by Toddler Age Group

Source: Household Health Survey Data, 2026

Figure 2 reveals that children aged one to three years accounted for the majority of diarrhea cases (75%). Infants younger than one year represented only 10% of reported cases, while children aged three to five years accounted for 15%. The concentration of cases among children aged one to three years may be associated with increased environmental exposure during early childhood development, when children become more mobile and frequently interact with potentially contaminated household environments.

Table 4. Incidence of Toddler Diarrhea According to Water Source

Water Source	Households Reporting Diarrhea (%)
Well Water	35
Piped Water	18
Purchased Water	21

Source: Household Survey Data, 2026

Table 4 demonstrates substantial variation in diarrhea incidence across different drinking water sources. Households relying on groundwater wells reported the highest prevalence of diarrhea (35%), whereas households using piped water reported the lowest prevalence (18%). Purchased water users reported intermediate levels (21%). These findings correspond closely with laboratory results indicating higher microbial contamination among groundwater sources.

Table 5. Incidence of Toddler Diarrhea According to Water Treatment Practices

Treatment Method	Diarrhea Incidence (%)
Boiling	17
Filtration	20
Untreated Water	30

Source: Household Survey Data, 2026

Households consuming untreated water experienced the highest incidence of toddler diarrhea (30%). By comparison, households adopting boiling and filtration practices reported considerably lower disease prevalence. This pattern suggests that household-level water treatment serves as an important protective factor against waterborne diseases.

## Association Between Drinking Water Quality and Toddler Diarrhea

To determine whether drinking water quality significantly influenced diarrhea occurrence, logistic regression analysis was performed.

Table 6. Logistic Regression Analysis of Factors Associated with Toddler Diarrhea

Variable	Coefficient (B)	Odds Ratio (OR)	p-value
Well Water vs. Piped Water	0.76	2.15	0.021
Untreated Water vs. Boiled/Filtered	0.56	1.75	0.042
Low Income vs. High Income	0.34	1.50	0.087
Low Education vs. High Education	0.29	1.34	0.122

Source: Statistical Analysis of Survey and Laboratory Data, 2026

The regression results demonstrate that drinking water source and household water treatment practices were statistically significant predictors of toddler diarrhea.

Households relying on groundwater wells were more than twice as likely to experience diarrhea among toddlers compared with households using piped water systems (OR = 2.15;  $p = 0.021$ ). Similarly, households consuming untreated water exhibited a significantly greater risk of diarrhea than households employing boiling or filtration methods (OR = 1.75;  $p = 0.042$ ). Although lower income and educational attainment were associated with increased diarrhea risk, these variables did not achieve statistical significance at the conventional 5% threshold. Nevertheless, the direction of the coefficients suggests that socio-economic disadvantage may indirectly contribute to disease vulnerability through reduced access to safe water and sanitation resources.

### Validation Through Health Facility Records

To enhance the reliability of survey findings, household-reported diarrhea cases were compared with records obtained from local healthcare facilities serving the study area.

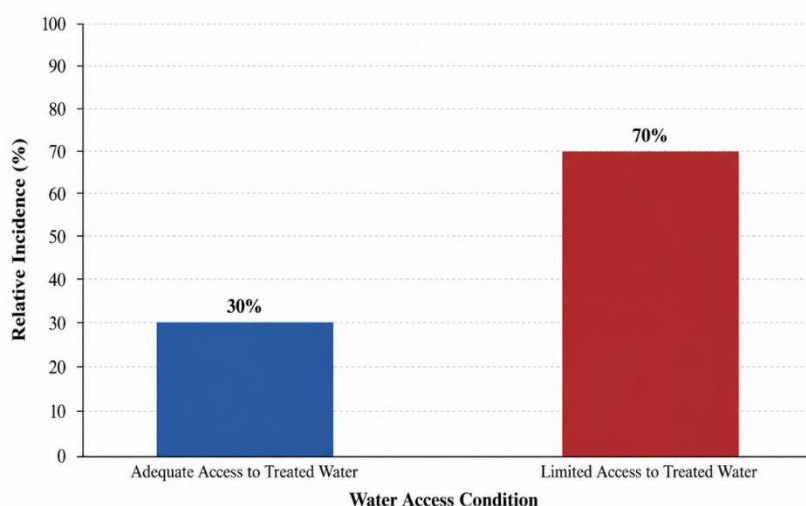
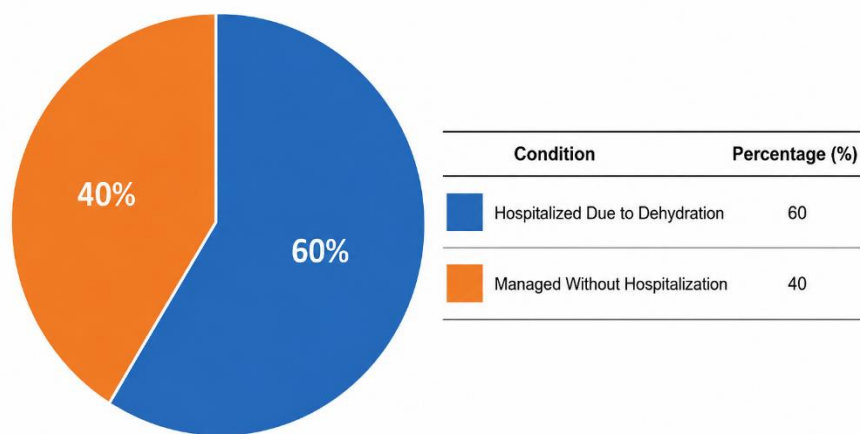


Figure 3. Incidence of Toddler Diarrhea According to Access to Treated Water

Source: Local Health Facility Records, 2026

Health facility data confirmed that neighborhoods characterized by inadequate access to treated water consistently reported higher numbers of diarrhea consultations among children under five years old. Approximately 70% of recorded diarrhea cases originated from communities with limited access to safe drinking water.



Source: Local Health Facility Records, 2026

Figure 4 demonstrates the substantial clinical burden associated with diarrheal disease. Approximately 60% of severe diarrhea cases recorded by local health facilities required hospitalization due to dehydration. This finding highlights the serious consequences of delayed treatment and prolonged exposure to unsafe drinking water. Review of health facility records further revealed that many caregivers delayed seeking medical assistance because diarrhea was initially perceived as a mild condition. Consequently, several cases progressed to dehydration before treatment was obtained.

### **Household Drinking Water Quality, Urban Environmental Vulnerability, and Toddler Diarrhea Risk**

The findings of this study provide strong evidence that household drinking water quality remains a critical determinant of toddler health in densely populated urban communities. The significant association between groundwater use, microbial contamination, and increased diarrhea incidence confirms that water safety continues to represent a major environmental health challenge despite ongoing improvements in urban water infrastructure. These findings support contemporary environmental health theories suggesting that health outcomes are not solely influenced by the availability of water but by the quality, safety, and management of water at the point of consumption (Wolf et al., 2022; Okesanya et al., 2024).

The elevated prevalence of *Escherichia coli* contamination in household well water observed in this study is consistent with recent international evidence demonstrating that groundwater sources in densely populated settlements are particularly vulnerable to fecal contamination. Similar findings have been reported in studies conducted in Sub-Saharan Africa, South Asia, and Southeast Asia, where inadequate sanitation systems and environmental overcrowding increase the probability of pathogen infiltration into groundwater supplies (Azanaw et al., 2024; Motuma et al., 2025; Al Wazni et al., 2023). The current study extends this evidence by demonstrating that comparable contamination pathways remain highly relevant in rapidly urbanizing Indonesian cities. Unlike many previous investigations that focused primarily on rural water insecurity, this study highlights how urban population density itself can become a significant environmental risk factor influencing waterborne disease transmission.

The strong relationship between untreated water consumption and toddler diarrhea further reinforces findings from recent systematic reviews that emphasize the effectiveness of household-level water treatment interventions. Wolf et al. (2022) demonstrated that boiling, filtration, and point-of-use treatment significantly reduce diarrheal disease among children in low- and middle-income countries. Similar

conclusions were reported by Dominguez-Rendón et al. (2024), who found that community-based water quality monitoring and household treatment practices substantially improve public health outcomes. The present findings therefore confirm that household behavioral interventions remain essential even when municipal water infrastructure is available. This observation is particularly relevant in urban settings where secondary contamination may occur during water storage and household handling (Aydamo et al., 2024; Azupogo et al., 2023; Beker & Kansal, 2024).

An important contribution of this study lies in its identification of socio-economic disparities as underlying determinants of water-related health risks. Although income and education variables were not statistically significant predictors within the regression model, their positive association with diarrhea incidence suggests that structural inequalities continue to shape exposure to environmental hazards (Dimitrova et al., 2023; Kazembe, 2022). This finding aligns with recent studies indicating that lower-income households often face multiple vulnerabilities simultaneously, including limited access to safe water, inadequate sanitation facilities, overcrowded housing, and reduced health literacy (Andrés et al., 2021; Evaristo et al., 2023; Okesanya et al., 2024). Consequently, the burden of childhood diarrhea should be understood not merely as a consequence of contaminated water but as a manifestation of broader environmental and social inequalities.

The study also contributes theoretically to the growing literature on urban environmental health by integrating water quality indicators, household behavior, sanitation conditions, and socio-economic characteristics within a single analytical framework. Existing studies frequently examine these variables independently; however, the current findings demonstrate that diarrheal disease emerges through interactions among environmental, behavioral, and socio-economic determinants. This multidimensional perspective supports integrated Water, Sanitation, and Hygiene (WASH) frameworks that conceptualize child health outcomes as products of interconnected environmental systems rather than isolated risk factors (Willets et al., 2022; Huang et al., 2023; Kalbar & Lokhande, 2023).

From a practical perspective, the findings suggest several important implications for public health policy. First, improving piped water coverage alone may not be sufficient to reduce diarrheal disease unless accompanied by regular water quality monitoring and infrastructure maintenance (Alum et al., 2024). Second, public health authorities should strengthen household-level interventions promoting boiling, filtration, and safe water storage practices. Third, targeted interventions should prioritize densely populated neighborhoods characterized by inadequate sanitation and high groundwater dependence. Recent evidence suggests that community-based monitoring programs and participatory water governance models can effectively improve household water safety while increasing public awareness regarding environmental health risks (Dominguez-Rendón et al., 2024; Lema, 2025).

This study is novel because it examines the contextual relationship between household drinking water quality and the prevalence of diarrhea in toddlers in densely populated urban areas in Manado City. The present research explores the pathways of exposure for households in an urban setting that is changing rapidly in terms of both demographic and infrastructural change, whereas the previous studies conducted on Indonesia have mainly concentrated on rural water access or on large-scale sanitation programs. The study brings together laboratory water quality assessment, household surveys and health facility records to offer a more comprehensive understanding of urban waterborne disease dynamics than is typically reported in the literature.

There are a number of caveats. First, the cross-sectional design does not allow for the establishment of causation since the exposure and outcome variables were both measured at the same time. Secondly, there is the possibility of recall bias in self-reported diarrhea episodes even if validated using health facility records. Third, water quality samples were taken on a single day and could not necessarily reflect seasonal fluctuations in water quality. Lastly, the study was conducted in selected densely populated districts of Manado City, which might not be generalizable to other urban areas with other socio-environmental characteristics.

Research in the future should use a longitudinal study to explore causality at a deeper level regarding the relationship between changes in water quality and child health outcomes over time. Seasonal variations in microbial contamination should also be studied, as well as the effectiveness of community based water management approaches and how climate related environmental changes affect urban waterborne disease risks. Comparative studies across several cities would also give interesting insights on the role of various urban development trends in household water safety and health outcomes of children.

## CONCLUSION

This study provides evidence that household water quality is still important for toddler diarrhea in the highly populated urban communities. Homes with groundwater wells had a higher proportion of microbial contamination, and higher rates of diarrhoea than those with treated piped water. The results also show that the use of household water treatment methods at the household level, specifically boiling and filtration, play an important role in decreasing the risk of disease for young children. The findings are consistent with the theoretical framework of environmental health outcomes that are the product of the interaction between water quality conditions, sanitation infrastructure, and household's environmental health behaviors.

Practically speaking, the study emphasizes the need for a multi-component approach to improve drinking water infrastructure, encourage regular water quality testing, promote home water treatment, and promote sanitation improvements. The key contribution of the study is the empirical evidence it offers with respect to water and health research in the context of a rapidly urbanizing city in Indonesia, which is not well-represented in current water and health research. There are several limitations to consider: cross sectional design, self-reported data may be subject to recall bias, and single-period water sampling. Longitudinal study designs, examination of differences in water contamination during various seasons of the year and testing the effectiveness of community-based water management interventions in different urban settings should be the focus of future studies. These would help create a clearer understanding of urban waterborne disease dynamics, and facilitate better public health policies protecting vulnerable child populations.

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