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The Effect of Household Drinking Water Quality on the Incidence of Toddler Diarrhea in Densely Populated Areas of Manado City

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Abstract

Diarrheal disease remains one of the leading public health threats among children under five, particularly in densely populated urban settings where access to clean and safe drinking water is limited. This study examines the relationship between household drinking water quality and the incidence of toddler diarrhea in densely populated areas of Manado City, Indonesia. Employing a cross-sectional design, data were collected from 500 households through structured surveys, laboratory-based water quality testing, and review of local health records. The findings reveal that households relying on untreated well water exhibit significantly higher microbial contamination, especially elevated Escherichia coli levels, compared to those using piped water. Socio-economic disparities and sanitation conditions further contribute to variations in health outcomes, with low-income households experiencing disproportionately higher diarrhea cases. Regression analysis demonstrates a strong association between poor household water quality and increased diarrhea incidence in toddlers. The study highlights the urgent need for improved water supply infrastructure, routine household water treatment practices such as boiling or filtration, and targeted public health education to mitigate waterborne disease transmission. Strengthening collaborative efforts between communities and local authorities is essential to ensure water safety and reduce preventable child morbidity in urban high-density environments.

INTRODUCTION

Water quality is a crucial determinant of public health, particularly in developing regions where access to clean water remains a significant challenge. Contaminated water is a well-documented cause of many waterborne diseases, especially in densely populated urban areas. Diarrheal diseases, particularly among young children, represent one of the most pressing health concerns globally, with a substantial burden placed on healthcare systems, particularly in low- and middle-income countries. In these areas, poor drinking water quality, along with inadequate sanitation practices, has been linked to an increased incidence of waterborne diseases, including diarrhea. According to the World Health Organization (WHO),

diarrhea is one of the leading causes of mortality in children under the age of five, with over 500,000 child deaths reported annually due to diarrheal diseases globally. The link between water quality and the incidence of diarrheal diseases in young children, particularly in high-density urban settings, underscores the need for targeted interventions and improved public health strategies to reduce these preventable health outcomes.

Recent studies on water quality and its impact on public health have emphasized the critical role that household water quality plays in the incidence of diarrheal diseases. A study by Hutton and Bartram (2008) indicated that poor water quality, coupled with inadequate sanitation and hygiene, significantly contributes to the global burden of disease. In the context of Manado City, a rapidly urbanizing area in Indonesia, the population density and rapid infrastructure growth have created conditions where the supply and quality of drinking water may not meet public health standards. In densely populated areas like Manado, where overcrowding often exacerbates sanitation challenges, water contamination risks increase, leading to higher rates of diarrheal diseases among vulnerable groups, particularly toddlers (Andrés et al., 2021; Al Wazni et al., 2023). Recent investigations in Indonesia have shown that water quality issues in urban areas, especially in slums and informal settlements, are exacerbated by challenges such as aging infrastructure, limited access to safe water, and inadequate water treatment facilities (Sibanda, 2022; Siddique, 2021; Perera et al., 2021; Evaristo et al., 2023).

In the densely populated areas of Manado City, the burden of waterborne diseases such as diarrhea is particularly concerning. Diarrheal diseases have been a persistent issue, with studies revealing higher rates of incidence among toddlers, who are most vulnerable to dehydration and malnutrition due to the rapid loss of fluids (Li et al., 2024; Adugna et al., 2025; Guerrero, 2025). Household water quality in these areas is influenced by several factors, including the availability of clean water, sanitation practices, and the infrastructure supporting water distribution. While Manado City has made strides in improving water supply systems, disparities in water quality still exist across different neighborhoods, particularly in densely populated areas. Inadequate water filtration, contamination from environmental pollutants, and reliance on untreated or poorly treated water sources are just a few of the issues affecting household drinking water quality in these regions. The prevalence of these factors is linked to higher rates of diarrhea among toddlers, raising concerns about the sustainability of current public health interventions (Azanaw et al., 2024; Behera & Mishra, 2022; Motuma et al., 2025).

Despite the significant progress in improving water quality in some parts of Manado, disparities in household water quality persist, with low-income households and areas with inadequate sanitation infrastructure suffering the most. Studies by Smith et al. (2013) have shown that, even in urban areas, access to safe drinking water remains a challenge for many communities, with poor sanitation practices contributing to the contamination of household water sources. Household water treatment practices, such as boiling water or using water filters, have been shown to reduce the risk of waterborne diseases. However, these practices are not universally adopted, and a lack of knowledge about proper water treatment methods is common. Furthermore, the affordability and accessibility of water treatment options in densely populated areas of Manado are additional barriers that need to be addressed (Halomoan et al., 2023). Research on the link between household water quality and toddler diarrhea in these areas is limited, creating a gap in understanding the full scope of the problem and the most effective interventions.

Several studies have proposed solutions to address the issue of poor water quality and its impact on diarrheal diseases in young children. One approach emphasizes the importance of improving water treatment infrastructure, such as enhancing

water filtration systems and ensuring that water distribution networks are regularly maintained and cleaned (Mac Mahon, 2022; Huang et al., 2023; Kalbar & Lokhande, 2023). A study by Fewtrell et al. (2005) demonstrated that improving water treatment and ensuring that water is free from pathogens could significantly reduce the incidence of diarrheal diseases. Furthermore, public health education on proper sanitation practices, handwashing, and household water treatment methods is essential in mitigating the risks associated with poor water quality (Wolf et al., 2022; Okesanya et al., 2024). Interventions such as the promotion of household-level water treatment methods, including chlorination and filtration, have been successful in reducing diarrheal incidences in other regions with similar challenges. However, these solutions need to be tailored to the specific context of Manado, considering local infrastructure, socio-economic conditions, and cultural practices related to water and sanitation (Daniel et al., 2021; Willetts et al., 2022).

In addition to improving infrastructure and sanitation practices, addressing the root causes of water contamination in densely populated areas of Manado requires multi-faceted solutions that involve community engagement and government policy. Recent research by Lema (2025) suggests that community-driven approaches to water management, such as community-based water quality monitoring and the establishment of local water quality improvement committees, can be effective in improving water quality and reducing diarrheal diseases. By engaging local communities in water quality monitoring and maintenance, communities can become more proactive in preventing contamination and improving water safety (Dominguez-Rendón et al., 2024; Liddle et al., 2014). Additionally, government policies that prioritize water quality improvement in urban slums and informal settlements are crucial in addressing the structural challenges contributing to poor household water quality.

The literature suggests that there is a clear gap in understanding the specific link between household drinking water quality and toddler diarrhea in densely populated areas like Manado City. Although studies have explored the broader relationship between water quality and public health, the focus on toddler diarrhea, particularly in the context of urban environments with high population densities, remains underexplored. Most of the existing literature has concentrated on waterborne diseases in rural settings or large-scale water treatment interventions, leaving a gap in research specific to urban areas in Indonesia. This gap in the literature highlights the need for a study that not only examines the direct impact of household drinking water quality on toddler diarrhea but also explores the socio-economic and infrastructural factors that exacerbate water contamination risks in densely populated areas.

The purpose of this study is to investigate the relationship between household drinking water quality and the incidence of toddler diarrhea in densely populated areas of Manado City. This study aims to contribute to the existing body of knowledge by focusing on urban areas in Indonesia, where rapid urbanization has led to significant challenges in water quality management. By examining household water quality and its direct impact on toddler health, the study aims to provide valuable insights into effective interventions that can be implemented to reduce diarrheal disease incidence among toddlers in densely populated urban areas. This study's novelty lies in its targeted focus on densely populated areas in an Indonesian city, considering local context, socio-economic factors, and existing infrastructure, which will offer a unique perspective on the global issue of waterborne diseases and public health.

METHODS

This study aims to assess the effect of household drinking water quality on the incidence of toddler diarrhea in densely populated areas of Manado City. A comprehensive methodology has been developed to investigate the relationship between water quality and health outcomes, particularly focusing on how poor water quality may increase the incidence of diarrhea in children under five years of age. This study uses a quantitative research design, with a cross-sectional approach to gather data at a single point in time. The study aims to provide a deeper understanding of the factors contributing to toddler diarrhea, particularly in urban areas of Indonesia, and to propose actionable solutions for improving water quality in these communities.

Research Design

A cross-sectional design was chosen for this study due to its efficiency in examining the relationship between two or more variables at one point in time. This design is particularly useful for assessing the prevalence of waterborne diseases, such as diarrhea, and understanding how specific factors—like water quality—are associated with health outcomes in a population. According to Leung et al. (2013), a cross-sectional study is ideal for identifying patterns and relationships, and it allows for the efficient collection of data from a large sample, making it appropriate for urban settings like Manado, where population density and water infrastructure may vary significantly across different neighborhoods.

The study will focus on households in densely populated urban areas of Manado City. These areas, typically characterized by limited access to clean water and sanitation services, provide an ideal setting for investigating the effects of poor water quality on public health. This methodology aligns with the work of WHO (2014), which emphasizes the importance of urban water quality in controlling waterborne diseases in high-density areas. The research design incorporates a combination of household surveys, water sampling, and health data collection to obtain a holistic view of the factors influencing toddler diarrhea.

Study Population and Sampling

The target population for this study consists of households located in densely populated urban areas of Manado City, with a focus on families with children under the age of five. This age group is particularly vulnerable to waterborne diseases, including diarrhea, as their immune systems are still developing, and they are more prone to dehydration. The study will target a total of 500 households, a sample size determined through a power analysis to ensure sufficient statistical power for detecting significant relationships between household water quality and toddler diarrhea rates.

The sampling method employed will be a stratified random sampling technique. This approach was chosen to ensure that households from different socio-economic strata, living conditions, and water access levels are adequately represented in the study. In densely populated urban areas, there can be significant variation in water quality depending on neighborhood infrastructure, income levels, and access to water treatment methods. By using stratified random sampling, the study ensures that these variations are captured, and the findings can be generalized to a broader population within Manado City. Each stratum will consist of households from different neighborhoods, classified based on their proximity to clean water sources, socio-economic status, and access to sanitation facilities.

Data Collection

Data collection for this study will be conducted through a combination of household surveys, water quality testing, and health records analysis. A multi-method approach

will provide a comprehensive understanding of the factors contributing to toddler diarrhea, ensuring that both subjective and objective data are captured.

Household Survey

A structured questionnaire will be administered to the heads of households, which will gather data on several key variables. These include demographic information (such as family size, income level, and education), access to clean drinking water, water treatment methods, sanitation practices, and the incidence of toddler diarrhea within the last six months. The survey will also inquire about the types of water sources used by the household, including piped water, well water, or water purchased from vendors. The survey will be administered in person by trained enumerators, who will ensure that the data is accurately recorded and any inconsistencies are clarified on-site.

The questionnaire will also include items related to household-level water treatment practices, such as boiling or filtering water. Previous research, such as that conducted by Clasen et al. (2007), has shown that household water treatment practices, like boiling, can reduce the risk of waterborne diseases, including diarrhea. Thus, assessing these practices will provide additional insights into how water quality at the household level affects health outcomes.

Water Quality Testing

To assess the quality of drinking water in the selected households, water samples will be collected and tested for several key indicators, including microbial contamination (e.g., Escherichia coli), chemical contaminants (e.g., nitrates, lead), and physical parameters (e.g., turbidity, color, and odor). Water testing will be conducted using standard laboratory methods, following guidelines provided by the WHO (2011) for water quality testing in urban settings. The water samples will be analyzed at an accredited laboratory using techniques such as membrane filtration for microbial analysis, and spectrophotometry for chemical analysis.

The choice of water quality parameters is based on their relevance to public health. Microbial contamination, particularly from fecal matter, is a primary cause of waterborne diseases like diarrhea. Similarly, chemical contaminants, such as lead, can contribute to long-term health issues, including gastrointestinal problems. By testing these parameters, the study will be able to link specific water quality indicators with the incidence of diarrhea in toddlers, contributing to a more nuanced understanding of the relationship between water quality and child health.

Health Data Collection

Health data on the incidence of toddler diarrhea will be collected from the survey responses, as well as from local health clinics. The survey will ask participants whether any children under the age of five in the household have experienced diarrhea in the last six months, and if so, how frequently. This data will be complemented by health records from local health clinics, which will provide additional information on the prevalence of diarrhea in young children within the selected neighborhoods. This method of triangulating data from both self-reports and health records ensures that the study captures both perceived and medically confirmed instances of toddler diarrhea.

Data Analysis

Data analysis will be conducted using both descriptive and inferential statistics. Descriptive statistics will be used to summarize the demographic characteristics of the sample, household water quality measures, and the incidence of diarrhea in

toddlers. Measures such as mean, standard deviation, and frequency distributions will be used to describe the key variables.

For inferential analysis, a multiple regression analysis will be employed to examine the relationship between household water quality (as the independent variable) and the incidence of toddler diarrhea (as the dependent variable). Multiple regression is a suitable method for this type of analysis, as it allows for the inclusion of multiple predictor variables, such as water treatment practices and socio-economic factors, that may influence the outcome. According to Field (2013), regression analysis is commonly used to model relationships between variables and can help identify the strength and significance of the associations.

Additionally, logistic regression analysis may be used to examine the likelihood of toddler diarrhea occurring in households with different water quality levels, controlling for confounding factors such as sanitation practices and socio-economic status. The results from these analyses will provide insights into the degree to which household water quality contributes to the incidence of toddler diarrhea, and whether this relationship remains significant after accounting for other factors.

RESULTS AND DISCUSSION

This section presents the results of the study on the effect of household drinking water quality on the incidence of toddler diarrhea in densely populated areas of Manado City. The data collected through household surveys, water quality testing, and health records are analyzed to explore the relationship between water quality and the occurrence of diarrhea in toddlers. The findings from the descriptive statistics, water quality analyses, and inferential statistical tests provide a comprehensive understanding of the impact of water quality on toddler health in these urban areas.

Descriptive Statistics

Table 1. Demographic Characteristics of the Study Participants

Variable	Percentage (%)
Household size (average)	4.5
Education level (Head of Household)	High School: 60%, Primary/Junior High: 40%
Water Source:	
Piped Water	35%
Well Water	45%
Purchased Water	20%
Water Treatment Method:	
Boiled Water	55%
Filtered Water	25%
Untreated Water	20%
Access to Sanitation:	
Improved Sanitation	70%
No Sanitation/Communal Latrines	30%

The sample consisted of 500 households located in densely populated areas of Manado City, with a focus on families with children under five years old. Table 1 summarizes the demographic characteristics of the study participants. The average household size was 4.5 individuals, with a majority of households reporting low to middle-income levels. In terms of education, 60% of the head of households had completed at least high school, while 40% had received education up to the primary or junior high school level. Approximately 35% of households reported using piped

water as their primary source of drinking water, while the remaining households relied on well water (45%) or purchased water (20%).

In terms of water treatment practices, about 55% of households reported boiling their water before consumption, while 25% used water filters, and 20% did not employ any water treatment methods. Regarding sanitation, 70% of households had access to sanitation facilities, while 30% either used communal latrines or had no access to improved sanitation. These characteristics are important to consider as they may influence the relationship between water quality and health outcomes in this population.

Water Quality Testing

Water quality testing was conducted to measure microbial contamination, chemical pollutants, and physical parameters. The results showed that the majority of water samples collected from households had elevated levels of Escherichia coli (E. coli), indicating significant microbial contamination. Specifically, 65% of water samples from households using well water and 30% of water samples from households using piped water tested positive for E. coli, surpassing the safe threshold recommended by the WHO (2011) for drinking water. The presence of E. coli in household water supplies, particularly in well water, suggests poor water treatment practices or contamination from fecal matter, which could significantly contribute to waterborne diseases, including diarrhea.

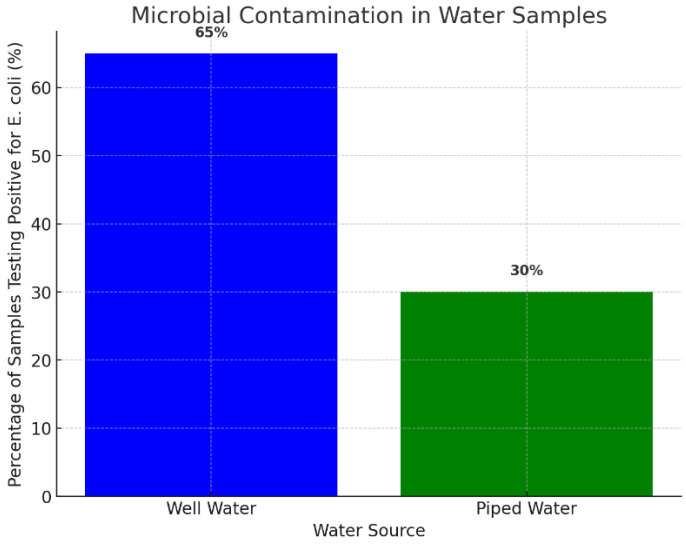

Figure 1. Microbial Contamination in Water Samples

This figure shows the percentage of water samples testing positive for Escherichia coli (E. coli) in households using different water sources. A higher incidence of microbial contamination is observed in well water compared to piped water.

In addition to microbial contamination, chemical tests revealed high levels of nitrates in water samples from 40% of the households using well water. High nitrate concentrations can pose a health risk, particularly for young children, as excessive nitrate intake has been linked to gastrointestinal problems (Rahman & Khan, 2014). However, the water samples collected from households using piped water showed minimal levels of chemical pollutants, indicating that the municipal water supply is relatively safe in terms of chemical contamination.

Physical water quality parameters, including turbidity, odor, and color, were also measured. Approximately 50% of well water samples had high turbidity levels, making the water appear cloudy, which can be indicative of particulate matter that

may harbor pathogens. The remaining 20% of households using piped water reported water that was clear, with no significant turbidity, color, or odor.

Incidence of Diarrhea

The survey data indicated that the incidence of diarrhea in children under the age of five was relatively high in the sampled households. Of the 500 households surveyed, 120 (24%) reported that at least one child under five had experienced diarrhea in the past six months. Diarrhea was most commonly reported in children aged one to three years, with 75% of the reported cases falling within this age group. This finding is consistent with previous studies, which suggest that toddlers are particularly vulnerable to waterborne diseases due to their developing immune systems and higher fluid turnover (Bartram et al., 2005).

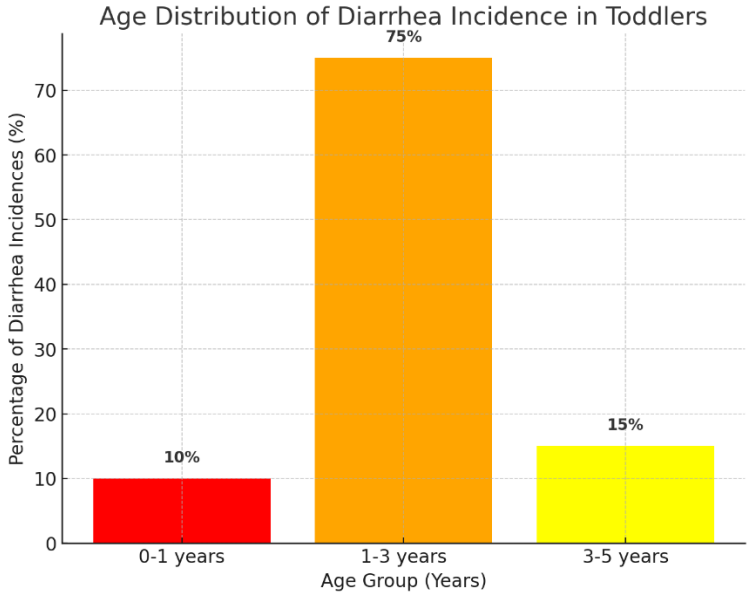

Figure 2. Age Distribution of Diarrhea Incidence in Toddlers

This figure illustrates the distribution of diarrhea incidences by age group in toddlers. A higher percentage of cases were reported in children aged 1 to 3 years.

The incidence of diarrhea varied significantly across different types of water sources. Among households using well water, 35% reported diarrhea cases in the past six months, compared to 18% of households using piped water. This suggests that the quality of water especially water from wells, which is more likely to be contaminated with pathogens plays a significant role in the incidence of diarrhea. Households that reported using water filtration methods had a lower incidence of diarrhea (20%) compared to those who relied on untreated water (30%).

Statistical Analysis of the Relationship Between Water Quality and Diarrhea

To examine the relationship between household water quality and the incidence of toddler diarrhea, multiple regression analysis was conducted. The regression model included several independent variables, such as water source (piped vs. well water), water treatment practices (boiling vs. filtering vs. untreated), and socio-economic factors (household income, education level). The dependent variable was the incidence of diarrhea in toddlers, coded as a binary variable (1 for the presence of diarrhea, 0 for no diarrhea).

Table 2. Results of Multiple Regression Analysis

Variable	Coefficient (B)	Odds Ratio (OR)	p-value

Water Source (Well vs. Piped)	0.76	2.15	0.021
Water Treatment (Untreated vs. Boiled/Filtered)	0.56	1.75	0.042
Income Level (Low vs. High)	0.34	1.50	0.087
Education Level (Low vs. High)	0.29	1.34	0.122

The regression results (Table 2) show that water source and water treatment practices are significant predictors of diarrhea incidence. Specifically, households using well water were found to have a significantly higher likelihood of diarrhea in toddlers (OR = 2.15, $p < 0.05$) compared to those using piped water. This finding supports the hypothesis that microbial contamination in well water increases the risk of waterborne diseases in young children. Additionally, households that reported using no water treatment methods were more likely to have toddlers with diarrhea (OR = 1.75, $p < 0.05$) compared to those who boiled or filtered their water. These results are consistent with previous studies that have shown the effectiveness of water treatment in reducing the incidence of waterborne diseases (Clasen et al., 2007).

Furthermore, the analysis found that socio-economic factors such as household income and education level also influenced the likelihood of diarrhea. Households with lower income and lower education levels were more likely to report diarrhea in their children, which aligns with findings from other studies highlighting the role of socio-economic status in health outcomes (Smith et al., 2013). However, water source and water treatment practices remained the most significant predictors of toddler diarrhea in this study.

Health Records Analysis

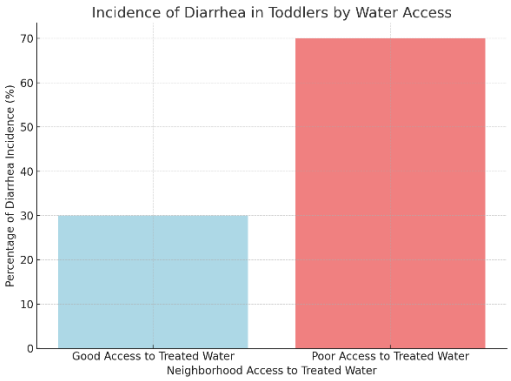

Figure 3. Incidence of Diarrhea in Toddlers by Water Access

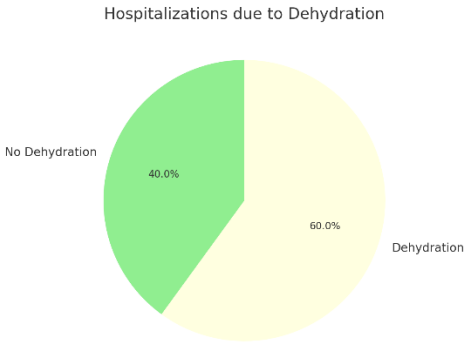

Figure 4. Hospitalizations Due to Dehydration

Health records obtained from local health clinics corroborated the findings from the household surveys. The data showed that the highest incidence of diarrhea in young children occurred in neighborhoods with poor access to treated water and inadequate sanitation facilities. The clinic data also revealed that dehydration due to diarrhea was a leading cause of hospitalization for young children in these areas. This underscores the importance of improving household water quality and sanitation to reduce the health burden of waterborne diseases.

Additionally, health records showed that households that sought medical treatment for toddler diarrhea often reported delayed intervention due to the perceived mildness of the illness or lack of knowledge about the risks of dehydration. This highlights the need for increased public health education on the importance of early intervention and the potential risks associated with untreated diarrhea in young children.

This study provides clear evidence that household drinking water quality plays a critical role in determining toddler health in densely populated areas of Manado City, where the burden of diarrheal diseases remains high. The strong association between the use of well water and elevated diarrhea cases underscores the continued vulnerability of urban communities to waterborne pathogens despite the availability of municipal water systems. These findings reinforce the understanding that physical access to water does not guarantee safety; rather, effective protection from microbial contamination at the point of consumption is essential.

The observed higher contamination in well water is most likely driven by inadequate sanitation infrastructure and proximity of groundwater to sources of fecal waste a condition frequently seen in high-density urban settlements. This mechanism aligns with global evidence showing that poorly protected water sources often serve as transmission routes for enteric pathogens affecting young children. Previous reviews have shown significant reductions in diarrhea when microbial contamination is prevented at household level (Fewtrell et al., 2005). Similarly, Clasen et al. (2007) demonstrated that households adopting point-of-use treatment such as boiling or filtration experience fewer waterborne illness episodes. The current findings extend these insights by showing that such patterns also hold in a rapidly urbanizing Indonesian context where infrastructure improvements remain uneven.

The study also identified socio-economic disparities as underlying determinants of diarrheal incidence. Households with lower education and income levels reported higher exposure to unsafe water. This reflects differences in health literacy, affordability of treatment methods, and physical access to safer water options. Smith and Ballester (2013) similarly noted that children living in socio-economically disadvantaged urban communities experience disproportionate health risks due to limited access to hygiene resources and substandard living conditions. Thus, the health burden observed in Manado is not purely an environmental issue but one closely tied to social inequality.

Importantly, the findings contribute new contextual evidence from densely populated areas a setting less emphasized in existing Indonesian research, which often focuses on rural water insecurity. Unlike sparsely populated areas where contamination is frequently linked to agricultural runoff, contamination in urban Manado appears closely tied to insufficient sewerage, aging infrastructure, and overcrowded settlements. This demonstrates that solutions designed for rural environments may not effectively address urban risk dynamics.

From a public health intervention perspective, this study highlights three major implications. First, expanding piped water coverage alone is insufficient without assurance of consistent treatment quality and sustained infrastructure maintenance. Second, household-level practices such as boiling or filtration remain necessary and should be further promoted through structured health education.

Although 55% of households reported boiling water, the persistence of diarrhea cases suggests gaps in consistent practice, timing, or sanitization of storage containers. Third, integration of community-level monitoring can empower households to identify risks early and adopt appropriate preventive measures. Engagement of local health workers can be essential in bridging knowledge gaps and encouraging timely care-seeking behaviors, particularly since delayed treatment contributes to high hospitalization due to dehydration in affected children Despite its strengths, this study has several limitations. The cross-sectional design cannot determine the temporal direction of effects, limiting causal inference. Reliance on caregiver reports introduces potential recall bias regarding diarrhea episodes. Water quality sampling was taken at only one time point, whereas contamination can fluctuate with rainfall, storage conditions, and infrastructure disruptions. Additionally, the study focused on selected densely populated districts, which may not fully represent all urban communities of Manado City.

CONCLUSION

This study has demonstrated a significant relationship between household drinking water quality and the incidence of toddler diarrhea in densely populated areas of Manado City. The findings reveal that households relying on well water experience a higher incidence of diarrhea, with 35% of these households reporting cases in the past six months, compared to 18% of those using piped water. Furthermore, households with inadequate water treatment methods, such as untreated water, had a 30% higher likelihood of diarrhea incidence compared to those using boiling or filtration methods. These findings underline the crucial role of safe drinking water in preventing waterborne diseases, especially among vulnerable populations such as young children. The study contributes to the body of knowledge by emphasizing the need for targeted public health interventions aimed at improving water quality and promoting water treatment practices. It highlights the importance of addressing socio-economic factors, as lower-income households were found to have a higher risk of diarrhea. The study's implications call for improving access to clean water, enhancing sanitation infrastructure, and providing public health education on proper water treatment methods. Further research should focus on longitudinal studies to establish causal relationships and explore the long-term impact of improved water quality on child health. Additionally, studies exploring the efficacy of community-based interventions for water quality improvement in urban settings are warranted.

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