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ANALYSIS OF AMOUNT OF WASTE, POPULATION, SOCIODEMOGRAPHY, WATER QUALITY AND DIARRHEA INCIDENCE

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Abstract

Introduction: *Diarrhea remains a major global health problem; however, evidence linking waste generation, population growth, sociodemographic factors, and water quality to diarrhea incidence at the local level is still limited. This study aimed to analyze these associations in Glagaharum Village, Porong Subdistrict, Sidoarjo.* ***Methods:*** *A quantitative cross-sectional study was conducted using primary and secondary data. A purposive sampling technique was applied to select households based on predefined criteria. Data were collected through questionnaires and water sampling. Water quality was analyzed using physical parameters (TDS, turbidity, and color) and microbiological parameters (total coliform). Data were analyzed descriptively and using correlation tests.* ***Results and Discussion:*** *A strong positive correlation (r = 0.90) was found between population growth and waste generation. The highest waste generation occurred in 2020. Most mothers had higher education (63%) and were not employed (37%). Physical water quality parameters exceeded standards (TDS 665 mg/L; turbidity 10.6 NTU; color 131.5 TCU). Total coliform was 17 CFU/100 mL, indicating microbiological contamination.* ***Conclusion:*** *Population growth and waste generation are strongly associated and may contribute to diarrhea incidence. Poor water quality, particularly microbiological contamination, is a potential risk factor. Although most mothers had higher education, variations in employment status and other sociodemographic factors may influence hygiene practices and disease risk.*

INTRODUCTION

Diarrhea remains one of the most prevalent infectious diseases globally, with approximately 1.7–2 billion cases reported each year. It is also a leading cause of mortality among children under five, causing around 760,000 to 1.9 million deaths annually, with nearly 99% of these deaths occurring in developing countries. The burden is particularly high in Africa and Southeast Asia, where about three-quarters of child deaths occur, especially among populations living in rural areas and those with low socioeconomic and educational status (1–2). Most of these deaths are preventable and are commonly associated with conditions such as poor sanitation, unsafe drinking water, and inadequate hygiene practices (1). Similar findings from Ghana

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identify environmental characteristics notably surface water which are uniformly positively correlated with diarrhea incidence, while other factors such as diurnal temperature range and density (population density) show negative relationships (3). Diarrhea is the second-leading cause of death in children under five years old, causing more than half a million deaths each year. At least 1 in 10 lacks access to safe drinking water, and as most of these deaths are attributed to unfit WASH conditions. Numerous risk factors including the quality of drinking water, sanitation, maternal education, economic situation and infant feeding practices still expose many developing areas to a higher occurrence of diarrhea (4).

Diarrhea incidence is also interrelated with human behavior, availability of clean water supply, safe wastewater disposal and environmental sanitation especially during the dry season. Overall, several interconnected factors contribute to the development of diarrheal disease. The most common risk factors associated with diarrhea are environmental factors such as clean water, drinking water quality, latrine utilization, household wastewater disposal, rubbish disposal, healthy homes and environments and clean and healthy living behavior in everyday life are also risk factors for the incidence of diarrheal disease. It is transmitted by contaminated food (food-borne disease), vectors in the form of flies (vector-borne disease) and unsafe water (water-borne disease) (5).

There is evidence in Ethiopia that improving the microbiological quality of drinking water can reduce diarrhea by as much as 39%, with better sanitation (about 30%), and better handwashing practices (around 30%). Moreover, the improper disposal of not only excreta but also household waste leads to breeding sites for vectors which are capable of transmitting diseases and therefore contributing to diarrhea risk (6). Furthermore, community-based waste banks can go a long way in operationalizing the Community-Based Total Sanitation program aimed at infecting change across its five pillars with an emphasis on helping communities to better hygiene and sanitation behaviors whilst advancing safe waste management and controlling wastewater at household sites (7).

There are many factors which can influence Diarrhea, including poor human waste management behavior and poor sanitation condition in household surroundings. Improper waste disposal creates a conducive environment for transmission of infectious diseases especially the waterborne ones such as diarrheal diseases. Waste management, one of the environmental sanitation fields, is still an unsolved problem in this developing country like Indonesia. Poor management of domestic waste leads to exposure and risk of disease transmission. *Rotavirus* and *Escherichia coli* are among the most prevalent microorganisms that cause diarrhea alone (8). Similarly, in India household environmental hazards (such as unprotected disposal of child faces and poor-quality flooring and roofing) were associated with a significantly increased risk of childhood diarrhea transmission (9).

This can cause environmental pollution as well as health hazards due to the inefficient management of waste. Unmanaged piles of waste can produce leachate with toxic heavy metals that pollute the environment (10). Insufficient waste management also indirectly threatens public health by creating conditions that favor the spread of vectors and pathogens (11). Also, improving sanitation infrastructure through standardized integrated waste management systems (for example, community waste banks/household waste segregation and environmental hygiene can lead to a reduction in the risk of diffuse diseases like diarrhea (10,12). People who take part of waste bank group programs likely make more efforts to reduce wastes in the community. These programs address effective waste sorting, create economic value, and reduce the amount of waste disposed of in landfills for more sustainable long-term healthcare (13). On a broader scale, solid waste management continues to be one of the most complex environmental health issues, requiring systematic public health interventions with significant community engagement (14).

Besides that, handling household waste, the water quality presence of *Escherichia coli* is also one of factors cause diarrhea. Clean water safe for public use must avoid *Escherichia coli* bacterial contamination with a standard of 0 in 100 ml of water (8). Multivariate analysis by multiple logistic regression reinforced these observations, with *Escherichia coli* contamination being the strongest correlate of diarrhea among the three key exposure variables in the Dinoyo Health Center zone (15). In the same taste, study that analyze relationship between drinking water quality on incidence of toddler with diarrhea at Masbagik Baru Health Center area in 2024 using Chi-square test also produced a p-value = 0.0000 < α soif this condition is not satisfied because p-value < α 5% that signifies there was statistically significant (16). In addition, a study in Bantarjaya Bogor found out that healthy clean-living behavior was able to prvent diarrhea (17). This includes good waste management practices and maintained environmental sanitation conditions. Research in Kolaka District basic sanitation refers to proper garbage, wastewater management and drinking water supply are essential for preventing diarrhea (18). The Community-Based Total Sanitation (CBTS)

programmed in Setu Sub-district, South Tangerang appears to be similarly effective in decreasing the occurrence of diarrhea among children < 5 years old as compared with a control site highlighting again the need for community-driven interventions (19). This makes community-wide involvement in environmental sanitation improvement and maintenance an essential aspect of diarrheal risk reduction. However, despite this existing evidence, studies integrating waste generation, population dynamics, sociodemographic characteristics, and water quality in a single analysis at the local level remain limited.

This study was conducted in Glagaharum Village, Porong Subdistrict, Sidoarjo, an area characterized by rapid population changes, proximity to industrial activities, and challenges in household waste management and access to safe water. These conditions may increase environmental exposure to contaminants and contribute to higher diarrhea risk. Therefore, this study aims to analyze the association between waste generation, population, sociodemographic factors, water quality, and diarrhea incidence in this specific local context.

METHODS

This study employed a quantitative design using a mixed ecological and household-level cross-sectional approach. Secondary data were used to analyze trends and associations at the regional level, while primary data were collected to provide contextual and environmental validation at the household level. Secondary data on waste generation, population, and diarrhea incidence were obtained from the East Java Provincial Environmental Office and the East Java Provincial Health Office. The unit of analysis consisted of all districts/municipalities in East Java Province over a three-year period (2020–2022). This period was selected based on the availability and completeness of comparable data across variables, enabling consistent trend and correlation analysis. Primary data were collected in Glagaharum Village, Porong Subdistrict, Sidoarjo District, which was selected due to its relatively high incidence of diarrhea and environmental sanitation challenges. This dual-scale approach was applied to complement regional-level findings with in-depth local-level observations. Household respondents were selected using purposive sampling with inclusion criteria: mothers with children under five years of age, residing in the study area for at least one year, and willing to participate. A total of 27 respondents were included in the study. Data were collected using structured questionnaires covering sociodemographic characteristics (education, occupation), household sanitation, water sources, and hygiene practices.

Water samples (clean water and drinking water) were collected from sampling points representing household water sources. Sampling was conducted following standard procedures for environmental water collection. Laboratory testing was performed at PT. Axo Green Laboratory, an accredited environmental laboratory (KAN No. LP-1348-IDN). The parameters analyzed included physical characteristics (temperature, Total Dissolved Solids/TDS, turbidity, color, and odor) and microbiological parameters (*Escherichia coli*). Water quality results were compared with applicable national drinking water and clean water quality standards. Two analytical approaches were applied. First, correlation analysis was conducted to examine the association between waste generation, population, and diarrhea incidence at the district/city level in East Java (2020–2022). Pearson correlation was used for normally distributed data, while Spearman correlation was applied when normality assumptions were not met. Prior to analysis, data were tested for normality and linearity. Second, descriptive analysis was used to summarize primary data, including sociodemographic characteristics, household sanitation conditions, and water quality parameters. These results were used to support the interpretation of environmental and behavioral risk factors associated with diarrhea at the local level.

RESULTS

Overview of Population and Amount of Waste in East Java (Year 2020–2022)

The graph in Figure 1 shows the population and amount of waste for three consecutive years 2020, 2021, and 2022 in East Java. The data is then compiled and analyzed based on the summation in each district/city in East Java Province. The green bar shows the population data and the red graph shows the amount of waste.

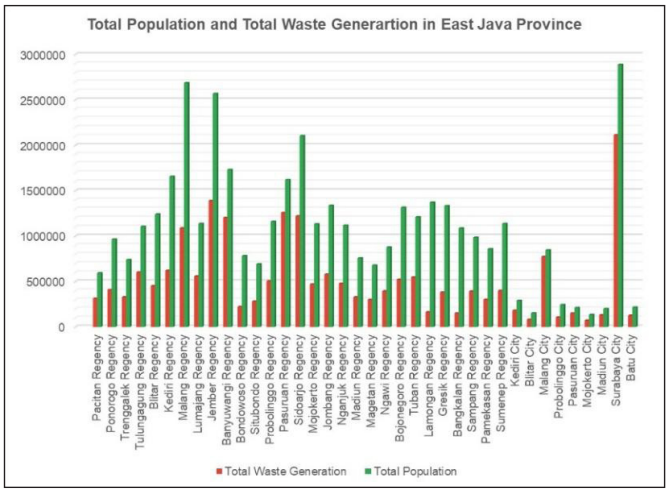

Figure 1. Graph of Total Population and Total Amount of Waste per Regency / City in East Java Province (2020 - 2022)

From the graph in Figure 1, areas with population above 15 million are Surabaya City, Malang Regency, Jember Regency, Sidoarjo Regency, Banyuwangi Regency, Kediri Regency and Pasuruan Regencies. These areas also have the largest waste production, especially Surabaya City, Jember Regency, Pasuruan Regency, Banyuwangi Regency, Sidoarjo Regency and Malang Regency. However, it can be seen that Kediri Regency is different from the other 8 regencies with a population relatively more, while the waste produced is less. In general, this is indicated by the line graph which shows an even pattern in East Java Province regencies and municipalities due to regions with large populations tend to produce more waste.

Overview of Waste and Diarrhea Incidence in East Java (Year 2020–2022)

The graph in Figure 2 shows the incidence of diarrhea and amount of waste for three consecutive years: 2020, 2021, and 2022. The data is then compiled and analyzed based on the summation in each district/city in East Java Province. The red bar graph shows the total amount of waste and the blue bar graph shows the total incidence of diarrhea. In the graph, the red bars represent this cumulative waste and the blue bars represent this total disease. Total of waste generation on Surabaya City that reached the highest (Figure 2). The regencies and municipalities with waste volumes over 1,000,000 include Jember, Pasuruan, Banyuwangi, Sidoarjo and Malang. The incidence of diarrhea also experienced a similar trend with the most cases coming from Sidoarjo, Surabayam Malang and Pasuruan.

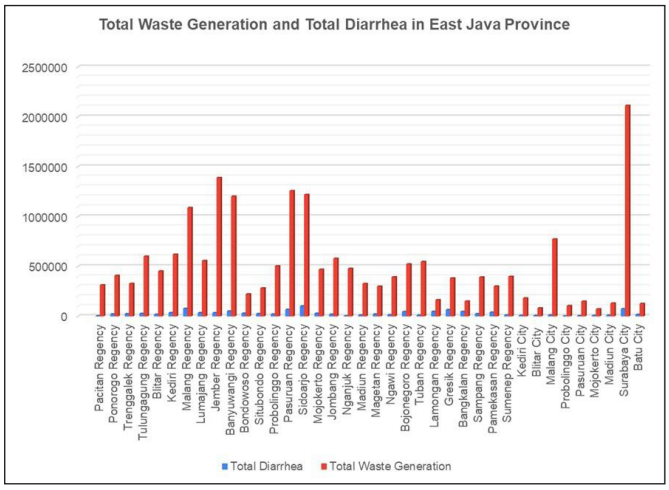

Figure 2. Graph of Amount of Waste and Diarrhea Incidence in East Java

On the contrary, Gresik is observed to produce a higher amount of diarrhea than its level of waste. On the other hand of Jember; Although has higher waste, number of people with diarrhea is still lower. Overall, the graph illustrates that higher generation of waste leads to more reporting of diarrhea incidence across districts/municipalities in East Java Province. The most waste producing three regions are Surabaya, Jember and Pasuruan.

Association of East Java Population and Amount of Waste

Table 1 presents the association analysis, which indicates that on district or municipality basis in East Java Province, waste generation is positively associated with population. Back up this finding with a trend in Figure 1. A significant association was observed in 2022 (r = 0.89), while similarly high correlations were also found in 2020 and 2021 (r = 0.88 for both years). Data is aggregated over the three year period 2020–2022 and this correlation coefficient rises from the yearly analyses to consecutive values of ~0.90, revealing a stronger interaction than previously discerned with just two datapoints per country per year.

Table 1. Association Analysis of Population and Amount of Waste in East Java

Year	Association Coefficient	Approximate Significance
2020	0.88	0.00
2021	0.88	0.00
2022	0.89	0.00

Association of Amount of Waste with Diarrhea Incidence in East Java (Year 2020–2022)

The analysis on the association at district/municipality level in East Java Province indicated a statistically significant and positive association between waste generation and diarrheal incidence. The peak at 2020 (r = 0.73) is followed by a drop for 2021 (r = 0.63), and then again increase in the next year, reaching once again the highest value for 2022 (r = 0.73). Overall, a cumulative-over-three-years association (2020–2022), on which we currently report, has a very strong link with values measured (r = 0.73) that is similar to that estimated for those taken in years 2020 and 2022.

Table 2. Association Analysis of Amount of Waste and Diarrhea in East Java

Year	Association Coefficient	Approximate Significance
2020	0.73	0.00
2021	0.63	0.00
2022	0.73	0.00
Total 3 Years	**0.73**	**0.00**

Table 3. Results of Laboratory Analysis of Physical and Biological Quality of Drinking Water and Clean Water in Porong Sub-district

Parameters	Quality Standard	Laboratory Results	
		Clean Water	Drinking Water
Physical			
Temperature	Water temperature ± 3°C	29 °C	29 °C
Total Dissolved Solid	< 300 mg/L	665 mg/L	244 mg/L
Turbidity	< 3 NTU	10.6 NTU	< 0.355 NTU
Color	10 TCU	131.5 TCU	< 2.54 TCU
Odor	No odor	No odor	No odor
Microbiology			
Escherichia coli	0 CFU/100 ml	17 CFU/ 100 ml	0 CFU/ 100 ml

DISCUSSION

These findings corroborate previous studies that have found a linear association between population size and waste production, or alternatively put, population growth results in an increased volume of waste produced (20). In addition, poor waste management identified as a main driver of diarrhea disease especially in children under 5 years old (21). Waste management too may be even more important than the other Water, Sanitation and Hygiene (WASH) components with regard to diarrhea incidence (22). So bad waste disposal practices/systems increase the environment pollution and risk of pathogens exposure to humans.

This relationship has also been well documented in other studies and highlights population dynamics as a critical influence on waste volume generation and the potential for subsequent environmental impact (23). The latter practice has been demonstrated to be effective in the reduction of diarrhea risk and highlights the relevance of integrated environmental health interventions (24). On the other hand, improper management of household waste is related to higher infectious diseases incidence (25), including diarrhea due to vector breeding and environmental contamination. This is further illustrated by the WASH framework, which identifies safe water supply and proper sanitation and hygiene practices as essential components for preventing diarrheal diseases (26–27).

Another supporting piece of evidence from a study in Indonesia showed significant correlations between environmental sanitation factors (like septic tank distance, waste accumulation and water source physical condition) attributes to microbial contamination especially *Escherichia coli* that can endanger human health as it contributes to diarrhea (28). Likewise, the East Java studies have reported an association between improper waste management practices and toddler diarrhea (29).

Yet there are studies that give contradictory results. Others found waste management not meaningfully associated with diarrhea incidence, indicating this relationship may be moderated/mediated by other contextual factors such as environmental conditions, sanitation infrastructure, and even community behavior (30). Sociodemographic factors contribute significantly to variations in the incidence of diarrhea. The study found that a large proportion of mothers had low education and were unemployed. The education of mothers is one of the most recognized determinants of child health including the risk and severity of diarrhea in children under five years old (31–32).

Lesser maternal education has also been associated with lower knowledge of hygiene and disease prevention, thereby increasing animal-transmitted infectious diarrhea (33). Apart from education, economic status has a critical role to play as well. Though most of the participants in this study fell into a middle-income category, others have highlighted that low income families are associated with an increased risk of childhood diarrhea (34). Nonetheless, there have been a few studies that report no direct relationship between health and economic status in terms of diarrhea incidence, where the health outcome was only found associated indirectly through factors such as maternal education, nutrition or availability of sanitation facilities (35). Second, economic factors are indirectly involved in some way with diarrhea by affecting the education of mothers or nutrition in children and so on, something that was described in the article.

The findings presented in the text are generally consistent with both global and local literature regarding the relationship between population growth, waste management, and diarrhea incidence. However, the inconsistencies noted in several studies that found no significant association between waste management and diarrhea were not accompanied by a critical discussion of the moderating or mediating factors that may account for these discrepancies. Furthermore, the discussion of sociodemographic factors, such as maternal education and economic status, remains largely descriptive, failing to explore the indirect pathways between variables that could contribute to a more holistic causal model. Therefore, the analysis needs to be strengthened through a multivariate approach capable of controlling

for confounding variables and systematically examining the relative contribution of each determinant to diarrhea incidence.

Clean Water Quality, Drinking Water, and *Escherichia coli* Presence in Glagaharum Village, Porong Sub-District, Sidoarjo District, 2024

Abstract This study aimed to analyze the quality of clean water in Glagaharum Village, Porong Sub-district. The requirements for clean water are based on Regulation of the Minister of Health of the Republic of Indonesia Number 2, 2023 and this research is a descriptive exploratory study to determine whether they do or do not meet clean water quality standards. Various physical parameters such as total dissolved solids (TDS), turbidity, and color have been found higher than permissible limits which can also indicate rampant contamination of water. The specific values that were observed are: TDS as 665 mg/L, Turbidity as 10.6 NTU and Color as overall color of 131.5 TCU respectively. On the other hand, the drinking water quality in study area mainly complies with standard set. The TDS levels found were higher when compared to other research that have been done in Kudus, Semarang with both results exceeding the limits (36). Wastewater contains hazardous contaminants that may pose significant risks to environmental health; consequently, its management must meet the required quality standards set by relevant regulatory authorities (37).

High TDS parameters are associated with water turbidity and high color parameters (38). Thus, regarding data obtained from both TDS parameters exceeded (chronic) environmental quality standards and turbidity and color also exceeded the maximum values set. Polluted water has higher TDS, turbidity and color values. A study from Gambia River, Africa has reported that rivers being upland in contact with high mining activities had the higher TDS and turbidity levels (39). This case is identical to water in the research sample location, namely waters in Lapindo mud (appeared due to mining activities).

Microbiological analysis indicated that the levels of *Escherichia coli* bacteria in clean water were 17 CFU/100 ml, where the allowable threshold according to regulation of the Minister of Health of the Republic of Indonesia Number 2 Year 2023 is a maximum value (< 1 CFU/100 ml). This means that the clean water prepared is not up to the required standard. Conversely, these standards are generally met by the drinking water samples. Swallowing water contaminated with *Escherichia coli* bacteria can also be a cause of diarrhea (40). This risk is even higher if drinking water and clean water are contaminated or total coliform exceeds the acceptable limits (41). These results are in line with other research, conducted in Garut where it was also found that well water contamination by *Escherichia coli* which met the environmental quality standard of clean water (42). Another study also stated that underground water began to be physically and biologically polluted. A survey indicated that some groundwater sources, particularly those obtained from wells, were contaminated with *Escherichia coli* bacteria (43). The study also analyzed the relationship between public health risks, one of which is the incidence of diarrhea because people can consume this water.

Various studies have demonstrated a strong relationship between drinking water quality and diarrhea ($p < 0.001$) (16). Moreover, a study in 2022 conducted in Bantarjaya Village, Bogor Regency, with $p = 0.000$ (< 0.05) found that waste management was associated with incidence of diarrhea. The study found that there was a strong association between poor management of waste and the occurrence of diarrhea (OR = 0.110). On the other hand, some earlier studies did not find a significant association between sanitation management and diarrhea incidence ($p = 0.129$) (30). This suggests that context specific factors are likely at play and highlight the need for region specific studies to examine the influence of waste management on its association with diarrheal disease (30).

Incidence of Diarrhea in Glagaharum Village, Porong Sub-district

In our study, 10% of the toddlers had complaints of diarrhea as gastric enteritis. Dehydration symptoms were observed in all victims, requiring treatment at the Porong Community Health Center. This study conducted an analysis of the relationship between waste volume and diarrhea incidence in East Java Province we obtained a strong correlation. It is also known that Sidoarjo District is still in the 5 large districts of waste producer in East Java province. This is consistent with data which states that Sidoarjo also still reported the highest number of diarrhea cases in East Java. The high volume of waste may substantially increase the risk of diarrhea among children under five, potentially having a greater impact than other hygiene and sanitation factors within the WASH framework (22). This is because waste contributes to the spread of disease through disease vectors such as flies and can contaminate air, soil, and water (44). Studies from India also highlight that beyond waste-related exposure, poor environmental hygiene and the use of unimproved sanitation facilities strongly increase diarrheal morbidity among young children.

Unsafe child stool disposal was likewise associated with a higher frequency of diarrheal episodes (9).

Furthermore, sociodemographic study using Glagaharum Village, Porong Subdistrict data shows that most of the mothers do not have a bachelor degree and almost half are working as laborers. The factors of parents, and specifically mothers, can contribute to a certain extent in the incidence of diarrhea among toddlers. Working mothers often have better education and knowledge related to diarrhea prevention (2). This level of knowledge can affect both household waste management practices and the risk of diarrhea. Poor waste management practices were associated with higher rates of diarrhea among mothers (45). For example, an absence of knowledge on how to avoid diarrhea could lead to poor handwashing leading and improper hygiene increase exposure to bacterial higher adherence to handwashing behavior is one of the highest influencing factor seen to mitigate diarrhea occurrence (46). Mother's knowledge of diarrhea is a major risk factor for diarrhea in toddlers Knowledge: Maternal knowledge about factors that causes diarrhea maternal knowledge on signs of diarrhea and first treatment can influence the incidence and severity (47).

As Glagaharum Village is located near the Lapindo mud flow site in Porong Sub-district, where many residents are known to suffer from water pollution that could lead to diarrhea, it put its risk and severity also here relatively higher than other regions. In addition to the physical and microbiological contamination of clean water where several parameters exceed environmental quality standards the surrounding environment is also affected by chemical pollution (48). A major contaminant is Polycyclic Aromatic Hydrocarbons (PAHs) typically found in volcanic mud (49). PAHs can promote activation of the inflammation in gut, leading to high permeability of the intestinal cells. This can result in loss of fluid and electrolytes leading to diarrhea (50). Time series analysis indicates spatial variation in ground level $PM_{2.5}$ may be indicative of general environmental contamination and sanitation in the area that can ultimately contribute to population susceptibility to diarrheal disease (51).

CONCLUSION

An association was found between population growth, waste generation, and diarrhea incidence, with the strongest correlation recorded in 2022 (r = 0.89) and a correlation of 0.90 between total waste and total population in East Java Province over 2020–2022. Cross-sectional analysis further revealed an association strength of 0.73 when accumulated waste and diarrhea data across all districts in East Java were analyzed over the same three-year period. Sociodemographic factors, particularly low maternal education and unemployment, were correlated with suboptimal household waste management, which in turn was associated with higher diarrhea incidence. Additionally, three physical parameters of clean water failed to meet the quality standards set by Indonesian Ministry of Health Regulation No. 2 of 2023, namely TDS (665 mg/L), turbidity (10.6 NTU), and color (131.5 TCU), while the microbiological parameter *Escherichia coli* also exceeded the permissible limit at 17 CFU/100 m.

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AUTHORS' CONTRIBUTION

RA: Conceptualization, Methodology, LS: Data curation, JJ: Writing Original draft preparation, RPU: Visualization, Investigation. MK: Software, Validation, NDA, ZAS, ZNN: Writing- Reviewing and Editing.

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