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Association Between Household Drinking Water Access and Management Factors and Diarrhea in East Kalimantan Province: Analysis Of SKAMRT 2024 Data

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Abstract: Diarrheal disease remains a significant public health concern and is closely associated with access to drinking water and household drinking water management practices. According to the 2023 Indonesian Health Survey (SKI), the reported prevalence of diarrhea was 4.3% nationally and 4.2% in East Kalimantan Province. This study aimed to examine the association between household drinking water access and management factors and diarrhea in East Kalimantan Province using data from the 2024 Household Drinking Water Quality Surveillance (SKAMRT). A cross-sectional study was conducted using secondary data from 2,051 households. The main independent variables were drinking water source, drinking water continuity, household drinking water treatment, and drinking water storage. Education of the household head, household size, and place of residence were included as covariates. Data were analyzed using descriptive statistics, bivariate analyses with the chi-square test, and multivariable logistic regression. The prevalence of reported diarrhea was 4.5%. After adjustment for the other variables included in the model, intermittent drinking water access was significantly associated with higher odds of diarrhea (AOR = 6.10; 95% CI: 3.21–11.57; $p < 0.001$). Unsafe drinking water storage was also significantly associated with higher odds of diarrhea (AOR = 2.67; 95% CI: 1.38–5.19; $p = 0.004$). Drinking water source and household drinking water treatment were not significantly associated with diarrhea. These findings highlight the importance of improving the reliability of the drinking water supply and strengthening household education on safe drinking water storage. These findings should be interpreted cautiously because of the cross-sectional design and reliance on household-reported diarrhea.

Keywords: Diarrhea; Drinking Water Continuity; Drinking Water Storage; East Kalimantan; SKAMRT 2024.

Introduction

Diarrhea is an infectious disease of the digestive tract caused by bacteria, viruses, and parasites. It is an environment-based disease because transmission is influenced by water conditions, sanitation, hygiene, and household environmental management. Diarrhea remains a global public health problem because of its contribution to morbidity and mortality. approximately 1.7 billion cases occur annually, with an estimated 443,832 deaths, particularly among vulnerable populations. Most cases are transmitted through the fecal-oral route, including drinking water contaminated by human or animal feces [1].

Currently, 2.1 billion people lack access to safely managed drinking water, of whom 302 million still use unimproved water sources [2]. The data indicate that the challenge of providing safe drinking water is still a global public health problem. However, the safety of drinking water is not only determined by the quality of the water source. Drinking water from relatively safe sources does not necessarily remain safe until consumption, as recontamination can occur during household-level transport, storage, and handling. Such contamination can occur through open storage containers, unhygienic water-drawing utensils, contaminated hands, and poor household sanitation and hygiene conditions [3].

Access and management of household drinking water play an important role in maintaining water security from source to consumption. Several studies have reported that these factors contribute substantially to the risk of diarrheal diseases. Households relying on unimproved water sources were reported to have higher odds of experiencing diarrhea compared with those using improved water sources [4]. Similarly, the absence of household drinking water treatment prior to consumption may increase the odds of diarrheal occurrence [5]. In addition, limited water access and unsafe storage practices may further increase the likelihood of pathogen contamination, thereby contributing to diarrheal disease transmission [6]. These findings show that access to drinking water and its management practices are important factors in the occurrence of diarrheal diseases.

In Indonesia, diarrhea remains an endemic disease and continues to impose a considerable burden on public health. The Indonesian Health Survey (Survei Kesehatan Indonesia/SKI) in 2023 reported a prevalence of diarrhea of 4.3% [7]. Furthermore, the 2024 Indonesia Health Profile documented more than three million diarrhea cases receiving healthcare services nationwide [8]. Although national access to improved drinking water sources will exceed 90% by 2024, access to safely managed drinking water remained substantially much lower, at less than 50% [9]. This gap indicates that increasing access to drinking water coverage alone may not be sufficient to reduce the burden of diarrheal

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disease unless accompanied by adequate household drinking water management practices.

At the regional level, diarrhea remains a public health concern in East Kalimantan Province, where the 2023 Indonesian Health Survey reported a prevalence of 4.2% [7]. East Kalimantan is undergoing substantial demographic and infrastructure changes associated with the development of Nusantara Capital City. In this context, ensuring reliable drinking water services and safe household water management is increasingly important for environmental health.

Drinking water access and management may influence diarrhea through several interconnected pathways. Intermittent access may limit water availability for hygiene, encourage households to use alternative sources, and result in longer periods of water storage. Inadequate treatment and unsafe storage may also allow contamination or recontamination before consumption, thereby increasing exposure to enteric pathogens.

Although numerous studies have examined the associations of water, sanitation, and hygiene with diarrheal disease, evidence on the combined role of household drinking water access and management remains limited, particularly at the provincial level in Indonesia. Previous studies have often examined drinking water source, treatment, or storage separately, without simultaneously assessing water-supply reliability and household management practices. In addition, few studies have used population-based drinking water surveillance data to investigate these factors in relation to household diarrhea.

The 2024 Household Drinking Water Quality Surveillance (SKAMRT) provides an opportunity to examine drinking water source, continuity, treatment, and storage simultaneously within a large provincial household sample. This study contributes provincial-level evidence for environmental health surveillance in East Kalimantan, where ongoing demographic and infrastructure changes underscore the importance of monitoring drinking water service reliability and household water management. Therefore, this study aimed to examine the associations between household drinking water access and management factors and diarrhea in East Kalimantan Province using the 2024 SKAMRT data.

Research Methods

Study Design

This study employed a quantitative analytical observational design using a cross-sectional approach. The design was used to examine the association between household drinking water access and management factors and the occurrence of diarrhea at the same point in time. The study utilized secondary data obtained from the 2024 Household Drinking Water Quality Surveillance (Surveilans Kualitas Air Minum Rumah Tangga, SKAMRT). Only data from East Kalimantan Province were analyzed.

Study Area and Period

The study was conducted in East Kalimantan Province using data from the 2024 SKAMRT. Data processing and statistical analyses were carried out between April and June 2026.

Population and Sample

The study population comprises ordinary households selected and recorded in the 2024 SKAMRT dataset. A total sampling approach was used, yielding a sample of 2,051 households, corresponding to all households recorded in the 2024 SKAMRT dataset.

Data Source

This study utilized secondary data obtained from the 2024 Household Drinking Water Quality Surveillance (SKAMRT), which was conducted by the Directorate of Environmental Health, Ministry of Health of the Republic of Indonesia. Data were collected through structured interviews using the standardized SKAMRT questionnaire administered by Environmental Health Officers from primary healthcare centers (Puskesmas) serving as field enumerators. Household selection in the SKAMRT was conducted using a two-stage cluster sampling method in accordance with the surveillance implementation guidelines.

Study Variables

The dependent variable was diarrhea. Diarrhea was defined according to the 2024 SKAMRT questionnaire as a condition in which at least one household member experienced three or more episodes of defecation per day with loose or watery stools during the previous month, or had been diagnosed with diarrhea by a healthcare professional (doctor, nurse, or midwife) during the same period.

The main independent variables included drinking water source, drinking water continuity, household drinking water treatment, and drinking water storage. Education of the household head, household size, and place of residence were included as covariates in the multivariable analysis to control for potential confounding. These covariates were selected based on their theoretical relevance and availability in the SKAMRT 2024 dataset.

Drinking water source was defined as the household drinking water source, classified by safety level as improved or unimproved. Improved sources included bottled water, refillable water, PDAM piped water, KPSPAM piped water, drilled or pumped wells, protected dug wells, protected springs, rainwater reservoirs, water hydrants, water terminals, and retail water purchased directly or from mobile vendors. Unimproved sources included unprotected dug wells, unprotected springs, and surface water from rivers, lakes, or irrigation canals.

Drinking water continuity was defined as the reliability of drinking water access, assessed by whether households experienced a drinking water shortage in the past year. It was categorized as continuous if households had not experienced any drinking water shortage lasting one month, and intermittent if such a shortage had occurred at least once during the previous year. Household drinking water treatment refers to any practice used by the household to treat drinking water before consumption. It was categorized as treated if the household reported treating the water before consumption, and untreated if no treatment was performed. Drinking water storage refers to the household practice of storing drinking water in certain containers before consumption. It was categorized as safe when drinking water was kept in covered pots or buckets, narrow-mouthed pitchers or containers, water gallons, or other covered ready-to-drink water containers, and unsafe when it was kept in uncovered pots or buckets.

Education of the household head was defined as the highest level of formal education completed by the household head, categorized as low if below senior high school and high if senior high school or above. Household size was defined as the number of individuals living permanently in the same household, categorized as ≤4 members and >4 members. Place of residence referred to the administrative classification of the household location, categorized as urban or rural.

Data Processing and Statistical Analysis

Data were processed and analyzed using IBM SPSS Statistics software. Data cleaning was performed by checking the completeness, consistency, coding, and range of each study variable before analysis. Descriptive analysis was used to present categorical variables as frequencies and percentages. Bivariate analysis was conducted using the chi-square test to assess the association between each main independent variable and diarrhea without controlling confounders. Crude odds ratios (ORs) and their corresponding 95% confidence intervals (95% CIs) were calculated. Multivariable binary logistic regression analysis was subsequently performed to estimate the adjusted associations between household drinking water access and management factors and diarrhea. Drinking water source, drinking water continuity, household drinking water treatment, and drinking water storage were included as the main independent variables. Education of the household head, household size, and place of residence were included as covariates to control for potential confounding, given their theoretical relevance and availability in the SKAMRT 2024 dataset. The results were reported as adjusted odds ratios (AORs) with 95% confidence intervals (95% CIs). Statistical significance was set at $p < 0.05$. All 2,051 households had complete data for the variables included in the analysis; therefore, no observations were excluded and no data imputation was required.

Ethical Considerations

This study used anonymised secondary data that contained no personal identifiers of respondents. All data were used solely for research purposes, and respondent confidentiality was strictly maintained throughout the study.

Results and Discussion

Based on the results of the univariate analysis presented in Table 1, among 2,051 households in East Kalimantan Province, 92 households (4.5%) reported diarrhea in the previous month, while 1,959 households (95.5%) did not report diarrhea. The majority of households (98.0%) used improved drinking water sources. The most common type of drinking water source was refillable water (69.9%), followed by PDAM piped water (10.5%). Regarding drinking water continuity, most households reported continuous access to drinking water or had never experienced a month-long shortage (96.5%). More than half of households treat drinking water (56.9%). Meanwhile, regarding drinking water storage, most households have safe drinking water storage (95.1%). Regarding household characteristics, most household heads had a high level of education, defined as senior high school or above (57.5%). Most households consisted of four or fewer members (67.8%), and more than half were located in urban areas (54.4%).

Table 1. Frequency Distribution of Study Variables

Variable	n (2051)	Percentage (%)
Diarrhea		
Yes	92	4.5
No	1959	95.5
Drinking water source		
Unimproved	42	2.0
Surface water (river/lake/irrigation)	15	0.7
Unprotected springs	12	0.6
Unprotected dug well	15	0.7
Improved	2009	98.0
Retail water is purchased directly from vendors	21	1.0
Retail water purchased from mobile vendors	2	0.1
Refillable water	1432	69.9
Bottled water	91	4.4
KPSPAM piped water	37	1.8
PDAM piped water	216	10.5
Water hydrant	2	0.1
Protected springs	36	1.8
Rainwater reservoir	31	1.5
Borewell/pump	90	4.4
Protected dug wells	51	2.5
Drinking water continuity		
Intermittent	71	3.5
Continuous	1980	96.5
Household drinking water treatment		
Untreated	883	43.1
Treated	1168	56.9
Drinking water storage		
Unsafe	100	4.9
Safe	1951	95.1
Education of household head		
Low	871	42.5
High	1180	57.5
Household size		
> 4 members	660	32.2
≤ 4 members	1391	67.8
Place of residence		
Rural	935	45.6
Urban	1116	54.4

The bivariate analysis presented in Table 2 showed that drinking water continuity ($p < 0.001$) and drinking water storage ($p < 0.001$) were significantly associated with diarrhea. Households with intermittent drinking water access had 7.29 times the odds of reporting diarrhea compared with households with continuous access (OR = 7.29; 95% CI: 3.99–13.31). Similarly, households with unsafe drinking water storage had 3.54 times the odds of reporting diarrhea compared with those using safe storage practices (OR = 3.54; 95% CI: 1.90–6.61). In contrast, drinking water source (p =

1.000) and household drinking water treatment (p = 0.271) were not significantly associated with diarrhea.

Table 2. Bivariate Analysis of Household Drinking Water Access and Management Factors and Diarrhea

Variable	Diarrhea				Total		OR	(95% CI)	p-value
	Yes		No						
	n	%	n	%	n	%			
Drinking water source									
Unimproved	1	2.4	41	97.6	42	100.0	0.514	(0.070–3.779)	1.000
Improved	91	4.5	1918	95.5	2009	100.0			
Drinking water continuity									
Intermittent	16	22.5	55	77.5	71	100.0	7.288	(3.991–13.307)	<0.001*
Continuous	76	3.8	1904	96.2	1980	100.0			
Household drinking water treatment									
Untreated	34	3.9	849	96.1	883	100.0	0.766	(0.497–1.181)	0.271
Treated	58	5.0	1110	95.0	1168	100.0			
Drinking water storage									
Unsafe	13	13.0	87	87.0	100	100.0	3.541	(1.896–6.614)	<0.001*
Safe	79	4.0	1872	96.0	1951	100.0			

*Statistically significant ($p < 0.05$)

The multivariable logistic regression analysis showed that drinking water continuity and drinking water storage remained significantly associated with diarrhea after adjustment for drinking water source, household drinking water treatment, education of the household head, household size, and place of residence. Households with intermittent drinking water access had 6.10 times the odds of reporting diarrhea compared with households with continuous drinking water access (AOR = 6.10; 95% CI: 3.21–11.57; $p < 0.001$). Households with unsafe drinking water storage had 2.67 times the odds of reporting diarrhea compared with households using safe drinking water storage (AOR = 2.67; 95% CI: 1.38–5.19; p = 0.004).

Table 3. Multivariable Logistic Regression Analysis of Household Drinking Water Access and Management Factors Associated with Diarrhea

Variable	n (%)	SE	B	p-value	AOR	95% CI
Drinking water source						
Unimproved	42 (2.0%)	1.036	-0.901	0.385	0.406	0.053–3.095
Improved	2009 (98.0%)				1.00 (Ref)	-
Drinking water continuity						
Intermittent	71 (3.5%)	0.327	1.808	<0.001*	6.097	3.212–11.572
Continuous	1980 (96.5%)				1.00 (Ref)	-
Household drinking water treatment						
Untreated	883 (43.1%)	0.232	-0.032	0.891	0.969	0.615–1.525
Treated	1168 (56.9%)				1.00 (Ref)	-
Drinking water storage						
Unsafe	100 (4.9%)	0.339	0.983	0.004*	2.672	1.375–5.193
Safe	1951 (95.1%)				1.00 (Ref)	-
Education of household head						
Low	871 (42.5%)	0.224	0.244	0.276	1.277	0.823–1.980
High	1180 (57.5%)				1.00 (Ref)	-
Household size						
> 4 members	660 (32.2%)	0.229	0.159	0.488	1.172	0.749–1.834
≤ 4 members	1391 (67.8%)				1.00 (Ref)	-
Place of residence						
Rural	935 (45.6%)	0.227	0.157	0.490	1.169	0.750–1.823
Urban	1116 (54.4%)				1.00 (Ref)	-

*Statistically significant ($p < 0.05$). AOR = adjusted odds ratio; CI = confidence interval; Ref = reference category. All variables were entered simultaneously using the Enter method.

This study examined the association between drinking water sources, drinking water continuity, household drinking water treatment, and drinking water storage and diarrhea in East Kalimantan Province, using secondary data from SKAMRT 2024. The prevalence of reported diarrhea in this study was 4.5%, which is slightly higher than the national average of 4.3% reported by the 2023 Indonesian Health Survey (SKI) [7].

Drinking Water Source

Multivariable analysis showed that drinking water source was not significantly associated with diarrhea after adjustment for drinking water continuity, household drinking water treatment, drinking water storage, education of the household head, household size, and place of residence (AOR = 0.41; 95% CI: 0.05–3.10; p = 0.385). This finding appears to be inconsistent with the theoretical expectation that drinking water may serve as an important vehicle for the transmission of enteric pathogens. A possible explanation for this finding is the drinking-water context in East Kalimantan. Almost all households (98.0%) used improved drinking water sources, with refillable water being the predominant source (69.9%). The improved category, therefore, represented a heterogeneous group that included refillable and bottled water, piped water, protected groundwater sources, and other water-supply arrangements. Classification as an improved source reflects the type and potential protection of the facility but does not necessarily represent microbiological safety at the point of consumption.

The predominance of refillable water may also have reduced the ability of broad source classification to distinguish differences in household exposure. Although refillable water is generally considered ready for consumption, its safety may depend on conditions at the refill facility and on subsequent transportation, transfer, storage, and withdrawal practices. Contamination or recontamination may occur after water has left the supply facility and before it is consumed [10].

Similar findings have been reported in previous studies, which found no significant association between drinking water sources and diarrhea. Access to an improved drinking water source alone may be insufficient to ensure water safety at the point of consumption because water can still become contaminated during distribution and household storage. Moreover, diarrhea transmission is also strongly influenced by environmental conditions, food consumption practices, and household sanitation behaviors [11], [12]. In contrast, other studies found a significant association between unimproved drinking water sources and diarrhea, suggesting that unimproved sources are more susceptible to pathogenic contamination and therefore may be associated with higher odds of diarrhea [13], [14]. Differences in source classification, source distribution, sanitation conditions, water quality, and household water-handling practices may explain variation across settings.

The estimate should also be interpreted cautiously because only 42 households used unimproved drinking water sources, and only one of these households reported diarrhea. The wide confidence interval indicates limited statistical precision and a reduced ability to detect differences between source categories. Therefore, the absence of a significant association does not indicate that the drinking water source is irrelevant to diarrhea; rather, it suggests that broad source classification alone may not adequately represent drinking water safety at the point of consumption in East Kalimantan.

Drinking Water Continuity

Multivariable analysis showed that intermittent drinking water access was significantly associated with diarrhea after adjustment for drinking water source, household drinking water treatment, drinking water storage, education of the household head, household size, and place of residence. Households with intermittent drinking water access had significantly higher odds of reporting diarrhea than households with continuous access (AOR = 6.10; 95% CI: 3.21–11.57; p < 0.001).

A possible explanation may relate to the drinking water context of East Kalimantan. Although most households reported continuous access, refillable water was the predominant source of drinking water. Household drinking water availability may therefore depend not only on piped water services but also on access to, transportation of, and regular purchase of commercially supplied water. During periods of insufficient availability, some households may rely on alternative sources, purchase water from different suppliers, or store larger quantities for longer periods. These practices could increase the risk of contamination during transportation, transfer between containers, storage, and withdrawal before consumption.

Depending on household water-use arrangements, drinking water shortages may also coincide with reduced availability of water for food preparation, handwashing, personal hygiene, and cleaning eating and drinking utensils. Longer storage periods may also be required to maintain a reserve supply, increasing the possibility of recontamination when containers are inadequately covered, infrequently cleaned, or repeatedly accessed using hands or utensils. These interconnected pathways may help explain why continuity remained significantly associated with reported diarrhea after adjustment for the other variables included in the model.

The finding is consistent with previous studies showing higher odds of diarrheal illness among households experiencing limited or unreliable water availability, whereas reliable or continuous water services have been associated with lower odds of diarrhea [15], [16], [17]. Water supply interruptions may contribute to this increased risk by reducing the amount of water available for drinking and hygiene, encouraging reliance on alternative water sources, and increasing household water storage, thereby facilitating recontamination and exposure to enteric pathogens [16], [18]. Nevertheless, these findings should be interpreted with caution because previous studies frequently assessed interruptions in piped water systems, whereas the present study defined continuity based on household-reported drinking water shortages during the previous year.

The findings reinforce the importance of monitoring the reliability of drinking water availability as population distribution and water demand patterns evolve. However, drinking water continuity was assessed over the previous year, whereas diarrhea was reported for the previous month. This difference in recall periods may have introduced exposure misclassification and should be considered when interpreting the association.

Drinking Water Treatment

Multivariable analysis showed that household drinking water treatment was not significantly associated with diarrhea after adjustment for drinking water source, drinking water continuity, drinking water storage, education of the household head, household size, and place of residence (AOR = 0.97; 95% CI: 0.62–1.53; p = 0.891). This finding appears inconsistent with the theoretical expectations that household water treatment should reduce diarrhea, as its primary purpose is to inactivate or remove pathogenic microorganisms before consumption.

The absence of a statistically significant association in this study may be due to recontamination of the treated water during storage. This contamination may occur when water is stored in uncovered containers, drawn with unhygienic utensils, or exposed to the contaminated hands of household members. The significant association between unsafe storage and diarrhea is consistent with the possibility that post-treatment handling may influence drinking water safety. Household treatment should therefore be considered alongside storage conditions and handling practices, rather than as an isolated activity. Additionally, a large proportion of households in this study used bottled or refillable drinking water. Households using refillable or bottled water may consider it ready for consumption and therefore report no additional treatment. Consequently, the untreated category may include both households that consume commercially supplied ready-to-drink water and households that consume untreated water from other sources. This heterogeneity may have reduced the treatment variable's ability to distinguish households with different levels of exposure to microbiological contamination.

Previous studies have also reported no significant association between household drinking water treatment and diarrhea in some settings [19], [20]. In contrast, other evidence has shown lower diarrhea occurrence when household water treatment was applied consistently and followed by safe storage practices [21], [22]. These inconsistent findings may reflect differences in treatment methods, source-water quality, treatment adherence, sanitation conditions, and post-treatment recontamination during storage and handling.

The absence of a significant adjusted association should not be interpreted as evidence that household drinking water treatment has no protective value. The SKAMRT variable classified treatment only as treated or untreated and did not capture the specific method, quality, frequency, consistency, or subsequent handling of drinking water. Therefore, the finding may reflect limitations in exposure classification rather than the absence of any potential benefit from appropriate household water treatment.

Drinking Water Storage

Multivariable analysis showed that unsafe drinking water storage was significantly associated with diarrhea after adjustment for drinking water source, drinking water continuity, household drinking water treatment, education of the household head, household size, and place of residence. Households using unsafe drinking water storage had significantly higher odds of reporting diarrhea than households using safe storage practices (AOR = 2.67; 95% CI: 1.38–5.19; p = 0.004). In theory, safe drinking water storage aims to prevent contamination of drinking water after it has been obtained or treated and before consumption. The use of hygienic storage containers that are tightly covered and equipped with a narrow opening or a dispensing tap is recommended to minimize direct hand contact with drinking water. By contrast, inadequately covered storage containers are more susceptible to contamination from dust, insects, splashed wastewater, contaminated hands, and unclean water-drawing utensils, thereby increasing opportunities for exposure to diarrheal pathogens [23], [24].

Previous evidence has linked wide-mouthed or inadequately covered storage containers with bacterial contamination and diarrhea occurrence because they are more susceptible to contamination during water handling [25]. Longer storage duration, infrequent container cleaning, and repeated refilling without removing residual water have also been associated with higher odds of diarrhea [26]. These findings suggest that drinking water safety may depend not only on the original source or treatment but also on how water is stored and handled until consumption [26], [27].

The adjusted association observed in this study is consistent with residual contamination during household storage and handling. This interpretation is also consistent with the overall pattern in which drinking water source and treatment were not significantly associated with diarrhea, whereas unsafe storage remained significant after adjustment. However, the broad safe–unsafe classification did not capture storage duration, container-cleaning frequency, dispensing practices, or the microbiological quality of stored water. These limitations should be considered when interpreting the association.

Overall, the pattern observed in this study may reflect the drinking water context in East Kalimantan, where refillable water was the predominant source. The absence of significant adjusted associations for drinking water source and household treatment, together with the significant associations observed for continuity and storage, suggests that drinking water safety may depend not only on the source or treatment used but also on the reliability of access and household handling practices up to the point of consumption. Transportation, transfer, prolonged storage, and withdrawal from containers may provide opportunities for contamination or recontamination. These findings highlight the importance of considering the entire household drinking water pathway, from access to consumption, when interpreting diarrhea-related associations in this setting.

Intermittent drinking water access and unsafe drinking water storage remained significantly associated with reported diarrhea after adjustment. However, residual confounding cannot be excluded because potentially important factors, including sanitation conditions, handwashing practices, household income, population density, and other household hygiene behaviors, were not available in the SKAMRT 2024 dataset. In addition, the cross-sectional design does not establish the temporal sequence between the exposures and diarrhea. Therefore, the findings represent adjusted statistical associations and should not be interpreted as causal effects. Future longitudinal studies incorporating more comprehensive sanitation, hygiene, socioeconomic, and microbiological water-quality indicators are needed to clarify these associations.

Despite these limitations, this study has several strengths. It used recent provincial surveillance data covering 2,051 households and simultaneously examined multiple dimensions of household drinking water access and management. The inclusion of multivariable analysis allowed the associations of the main exposure variables with diarrhea to be estimated after adjustment for selected household characteristics. The findings, therefore, provide relevant evidence for environmental health programs and drinking water surveillance in East Kalimantan, although the findings remain subject to the limitations of secondary cross-sectional data.

Research Limitations

This study employed a cross-sectional design to examine the associations between drinking water source, drinking water continuity, household drinking water treatment, drinking water storage, and diarrhea. Consequently, the temporal sequence between exposure and outcome could not be established, and causal relationships cannot be inferred. In addition, the diarrhea variable was derived from secondary data obtained from the 2024 SKAMRT survey and was based on self-reported information provided by household respondents. Therefore, the assessment of diarrhea occurring during the previous month may have been subject to recall bias. Furthermore, several potentially important confounding factors, including sanitation conditions, handwashing practices, household income, population density, and other hygiene-related behaviors, were not available in the SKAMRT 2024 dataset. The absence of these variables may have resulted in residual confounding and should be considered when interpreting the study findings. In addition, the broad binary classifications of household water treatment and storage may not have fully captured treatment methods, storage duration, cleaning frequency, or post-treatment handling practices.

Conclusion

This study found that intermittent drinking water access and unsafe drinking water storage remained significantly associated with reported diarrhea after adjustment for drinking water source, household drinking water treatment, education of the household head, household size, and place of residence. These findings support efforts to improve the reliability of drinking water supply and promote safe household water storage practices. Environmental health programs may consider incorporating water supply continuity and safe storage practices into drinking water surveillance and diarrhea prevention strategies. However, these findings represent statistical associations and should not be interpreted as evidence of causal relationships because of the cross-sectional design. In addition, diarrhea was based on household reports and may have been affected by recall or reporting bias. Future longitudinal studies incorporating sanitation, hygiene, socioeconomic, and microbiological water-quality indicators are recommended.

Author's Contributions

A. Riyadi: Conceptualization, methodology, data analysis, interpretation of results, and writing, original draft. B. Wispriyono: Conceptualization, methodology, supervision, validation, and writing, review and editing. Both authors reviewed and approved the final manuscript.

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References

[1] World Health Organization (WHO), "Diarrhoeal disease." Accessed: Dec. 29, 2025. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

[2] World Health Organization (WHO) & United Nations Children's Fund (UNICEF), "Progress on Household Drinking Water, Sanitation and Hygiene 2000–2024: Special Focus on Inequalities," WHO/UNICEF Joint Monitoring Programme, Geneva, 2025.

[3] A. Kundu, W. A. Smith, D. Harvey, and S. Wuertz, "Drinking water safety: Role of hand hygiene, sanitation facility, and water system in semi-urban areas of India," *Am. J. Trop. Med. Hyg.*, vol. 99, no. 4, pp. 889–898, 2018, doi: 10.4269/ajtmh.16-0819.

[4] G. Mulatu *et al.*, "Association of drinking water and environmental sanitation with diarrhea among under-five children: Evidence from Kersa demographic and health surveillance site, eastern Ethiopia," *Front. Public Heal.*, 2022, [Online]. Available: https://doi.org/10.3389/fpubh.2022.962108

[5] N. Agustia, "Hubungan Pengolahan Air Minum dan Pendapatan Keluarga dengan Kejadian Diare Pada Balita di Kecamatan Baturaja Barat Tahun 2021," *Cerdika J. Ilm. Indones.*, vol. 2, no. 2, pp. 206–212, 2022, doi: 10.59141/cerdika.v2i2.324.

[6] A. W. Bivins *et al.*, "Estimating Infection Risks and the Global Burden of Diarrheal Disease Attributable to Intermittent Water Supply Using QMRA," *Environ. Sci. Technol.*, vol. 51, no. 13, pp. 7542–7551, 2017, doi: 10.1021/acs.est.7b01014.

[7] Kementerian Kesehatan RI, "Survei Kesehatan Indonesia (SKI) 2023," Badan Kebijakan Pembangunan Kesehatan, Kementerian Kesehatan Republik Indonesia, Jakarta, 2024.

[8] Kementerian Kesehatan RI, "Profil Kesehatan Indonesia 2024," Jakarta, 2025.

[9] Kementerian Kesehatan RI, "Hasil Surveilans Kualitas Air Minum Rumah Tangga Tahun 2024 (Dalam Angka)," Direktorat Kesehatan Lingkungan, Direktorat Jenderal Penanggulangan Penyakit, 2026.

[10] R. Bain, R. Cronk, J. Wright, H. Yang, T. Slaymaker, and J. Bartram, "Fecal Contamination of Drinking-Water in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis," *PLoS Med.*, vol. 11, no. 5, 2014, doi: 10.1371/journal.pmed.1001644.

[11] N. E. Soboksa, "Associations Between Improved Water Supply and Sanitation Usage and Childhood Diarrhea in Ethiopia: An Analysis of the 2016 Demographic and Health Survey," *Environ. Health Insights*, vol. 15, 2021, doi: 10.1177/11786302211002552.

[12] P. A. Torres-Slimming *et al.*, "Diarrheal disease and associations with water access and sanitation in Indigenous Shawi children along the Armanayacu River basin in Peru. Rural and Remote Health," *Rural Remote Health*, vol. 23, no. 3, p. 7198, 2023, [Online]. Available: https://doi.org/10.22605/RRH7198

[13] A. M. Girmay *et al.*, "Associations of WHO/UNICEF Joint Monitoring Program (JMP) Water, Sanitation and Hygiene (WASH) Service Ladder service levels and sociodemographic factors with diarrhoeal disease among children under 5 years in Bishoftu town, Ethiopia: a cross-sectional st," *BMJ Open*, vol. 13, no. 7, pp. 1–11, 2023, doi: 10.1136/bmjopen-2022-071296.

[14] I. Adamu, F. C. D. Andrade, and C. R. Singleton, "Availability of Drinking Water Source and the Prevalence of Diarrhea among Nigerian Households," *Am. J. Trop. Med. Hyg.*, vol. 107, no. 4, pp. 893–897, 2022, doi: 10.4269/ajtmh.21-0901.

[15] S. Hubbard *et al.*, "Household Illness and Associated Water and Sanitation Factors in Peri-Urban Lusaka, Zambia, 2016–2017," *NPJ Clean Water*, vol. 3, no. 1, 2020, doi: 10.1038/s41545-020-0076-4.

[16] C. N. Mock, K. R. Smith, R. Nugent, O. Kobusingye, and A. Alwan, "Injury prevention and environmental health (English)," 2017. doi: 10.1596/978-1-4648-0522-6_ch9.

[17] J. Wolf *et al.*, "Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression," *Trop. Med. Int. Heal.*, vol. 23, no. 5, pp. 508–525, 2018, doi: 10.1111/tmi.13051.

[18] J. Trudeau, A.-M. Aksan, and W. F. Va´squez, "Water system unreliability and diarrhea incidence among children in Guatemala," 2017, doi: 10.1007/s00038-017-1054-6.

[19] C. Okolimong, E. Walekula, S. Orech, D. Okia, D. Mukunya, and P. Olupot-Olupot, "Association of diarrheal disease with solid waste management practices and perceptions among residents of industrial division in Mbale City: a cross sectional study," *BMC Public Health*, vol. 26, no. 1, 2026, doi: 10.1186/s12889-026-26463-9.

[20] D. Mosisa, M. Aboma, T. Girma, and A. Shibru, "Determinants of diarrheal diseases among under five children in Jimma Geneti District, Oromia region, Ethiopia, 2020: a case-control study," *BMC Pediatr.*, vol. 21, no. 1, pp. 1–13, 2021, doi: 10.1186/s12887-021-03022-2.

[21] B. Kalakheti, K. Panthee, and K. C. Jain, "Risk Factors of Diarrhea in Children Under Five Years in Urban Slums," *J. Lumbini Med. Coll.*, vol. 4, no. 2, p. 94, 2016, doi: 10.22502/jlmc.v4i2.99.

[22] G. Tubatsi, M. C. Bonyongo, and M. Gondwe, "Water use practices, water quality, and households' diarrheal encounters in communities along the Boro-Thamalakane-Boteti river system, Northern Botswana," *J. Heal. Popul. Nutr.*, vol. 33, no. 1, pp. 1–12, 2015, doi: 10.1186/s41043-015-0031-z.

[23] R. Meierhofer and S. Peter, "Household Water Treatment and Safe Storage (HWTS): Sandec Training Tool 1.0 – Module 3," Eawag/Sandec, Department of Water and Sanitation in Developing Countries, Dübendorf, Switzerland, 2008. [Online]. Available: https://www.eawag.ch

[24] World Health Organization (WHO), "Drinking-water." Accessed: Mar. 12, 2026. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/drinking-water

[25] R. V. N. Sangma, S. K. Rasania, J. G. Prasuna, R. Das, and M. Jais, "Bacteriological quality of drinking water and diarrhoeal outcome among under five children in resettlement colony, Delhi: A community-based study," *Proc. World Congr. New Technol.*, vol. 0, no. August, pp. 1–8, 2019, doi: 10.11159/icepr19.187.

[26] M. G. Abera, A. A. Werkneh, R. S. Welde, M. A. Islam, and G. H. Redae, "Diarrhea prevalence and water, sanitation, and hygiene (WASH) factors among internally displaced children under-five in Mekelle city, Northern Ethiopia," *Clin. Epidemiol. Glob. Heal.*, vol. 28, no. June, p. 101660, 2024, doi: 10.1016/j.cegh.2024.101660.

[27] K. Fagerli *et al.*, "Comparison of boiling and chlorination on the quality of stored drinking water and childhood diarrhoea in Indonesian households," *Epidemiol. Infect.*, vol. 145, no. 15, pp. 3294–3302, 2017, doi: 10.1017/S0950268817002217.