

Children's Health Vulnerability to Climate Change: An Analysis of the Relationship between Floods, Environmental Sanitation and Infectious Diseases in Children Under Five Years of Age

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ABSTRACT

Background: Floods can compromise household sanitation and expose young children to infectious hazards. Objective: To examine the associations of flood exposure and environmental sanitation with reported infectious illness among children aged 12–59 months in Koto Tangah, Padang. Methods: The manuscript describes a cross-sectional survey of 152 mothers/caregivers conducted January–May 2026, using questionnaires and household observation. Associations were analyzed using chi-square tests and multiple logistic regression. Results: Reported infectious illness affected 56/152 children (36.8%), including 32/61 (52.5%) in high-flood-exposure households and 24/91 (26.4%) in low-exposure households. High flood exposure was associated with illness in the reported multivariable model (aOR 2.48; 95% CI 1.27–4.85); abnormal nutritional status was also associated (aOR 1.89; 95% CI 1.01–3.54). Sanitation indicators did not retain conventional statistical significance after adjustment. Conclusion: The presented results suggest an association between household flood exposure and reported childhood illness, but causal inference is precluded by the cross-sectional design. The source dataset and analytical output must be verified before reporting these figures as empirical findings.

Keywords: Flood Exposure, Environmental Sanitation, Infectious Diseases, Climate Change, Nutritional Status

INTRODUCTION

Climate change is associated with changes in precipitation patterns and extreme rainfall, with important implications for flood-related health risks (IPCC, 2021). Flooding can disrupt drinking-water services, damage toilets and wastewater systems, and increase contact with

potentially contaminated water. Children aged under five years may be particularly vulnerable because of their developmental stage, reliance on caregivers, and frequent contact with household environments. However, attributing an individual flood event to climate change requires analyses beyond the scope of a household cross-sectional survey. This study therefore examines flood exposure as a climate-sensitive environmental hazard rather than directly measuring climate-change effects.

One of the most obvious manifestations of climate change in tropical regions like Indonesia is the increasing incidence of flooding. Indonesia's geographical location, crossed by thousands of river basins, coupled with high seasonal rainfall, places many densely populated residential areas in flood-prone zones (Adi et al., 2022). Data from the Indonesian Disaster Risk Index shows that flooding is among the most frequent hydrometeorological events in various provinces, and this trend is projected to continue to increase as extreme rainfall intensification driven by climate change (Adi et al., 2022; IPCC, 2021). This increased frequency of flooding places vulnerable groups, particularly children under five, at greater health risk than other age groups.

Toddlers are a group that is still physiologically and immunologically developing, so their immune system against infectious agents has not yet developed optimally. Their immature immune systems make them more susceptible to infections transmitted through contaminated water, food, and environmental contact. In addition to physiological factors, toddlers are also highly dependent on their living environment and parenting patterns, as they are not yet able to independently avoid risk exposure or practice hygienic behaviors. This combination of biological immaturity and environmental dependence makes toddlers the group most impacted when environmental health crises occur due to hydrometeorological disasters (Al Wazni et al., 2023).

Flooding directly changes the quality of residential environments through the contamination of clean water sources and damage to basic sanitation facilities. Floodwater mixed with domestic waste, human and animal waste, and garbage creates a highly conducive medium for pathogen transmission. Dimitrova et al. (2022) in a global analysis of 32 low- and middle-income countries found that high rainfall anomalies were associated with an increased risk of diarrhea, coughing, and fever in children under five, particularly in areas with limited access to sanitation. These findings confirm that the health impacts of flooding do not stand alone but are strongly mediated by environmental sanitation conditions that existed before and after the disaster.

Environmental sanitation plays a crucial role in the chain of disease transmission after flooding. The availability of sanitary latrines, wastewater management systems, waste management, and access to adequate clean water determine how well a community can withstand the health impacts of flooding. In areas where basic sanitation is already inadequate before a disaster, flooding tends to exacerbate these conditions by damaging existing sanitation infrastructure, increasing the likelihood of residents, particularly children under five, coming into contact with water and environments contaminated with pathogens (UNICEF, 2023). This creates a cycle of vulnerability: poor sanitation exacerbates the impact of flooding, and flooding, in turn, further damages the remaining sanitation.



Evidence from international and Indonesian studies indicates that hydrometeorological hazards, household sanitation and childhood infection are interrelated but not necessarily interchangeable exposures. Dimitrova et al. (2022) reported associations between precipitation variability and childhood illness across low- and middle-income countries, while Wang et al. (2023) examined flooding and diarrhea in young children. Indonesian evidence has also linked household environmental conditions to diarrhea and respiratory infections (Mubarokah & Sartika, 2022; Zolanda et al., 2021). Nevertheless, these studies differ in disease definitions, exposure timing and sanitation measurements; their associations should not be assumed to apply uniformly to all post-flood settings.

Similar evidence is also found in the international context. Research in flood-prone areas of Northwest Ethiopia reported a diarrhea prevalence of 29.0% among children under five in settlements regularly affected by flooding, with poor basic sanitation as a key predictor (Birhan et al., 2023). Al Wazni et al. (2023) also confirmed that improved water, sanitation, and hygiene (WASH) infrastructure plays a significant role in reducing diarrheal disease mortality among children under five in climate-vulnerable countries. These findings consistently demonstrate that the relationship between hydrometeorological crises and infectious diseases in children cannot be fully understood without considering the role of environmental sanitation as a connecting variable.

A specific evidence gap concerns the simultaneous evaluation of household-level flood exposure, multiple sanitation domains, and reported childhood infectious illness within the same flood-prone Indonesian setting. Existing studies often focus on individual diseases or a narrower set of environmental exposures, limiting the ability to compare flood exposure and different sanitation indicators within one statistical model. Moreover, household sanitation may correlate with flood exposure and with other socioeconomic characteristics, making adjusted estimates important.

The present study addresses this gap by jointly assessing flood history, toilet adequacy, solid-waste management, wastewater management, clean-water access, and selected maternal and child characteristics in Koto Tangah, Padang. Its contribution is context-specific comparative evidence on these associations; the cross-sectional design does not establish temporal ordering, mediation, climate attribution, or causality. The study also distinguishes individual sanitation indicators from the overall sanitation classification.

This study aimed to determine whether high household flood exposure and inadequate environmental sanitation were associated with reported diarrhea, acute respiratory infection, or skin disease among children aged 12–59 months, and whether associations persisted after adjustment for maternal and child characteristics. The prespecified working hypothesis was that greater flood exposure and poorer household sanitation would be associated with higher odds of reported infectious illness.

METHODS

Study design and setting. An analytical cross-sectional study was described to examine the association of household flood exposure and environmental sanitation with caregiver-reported infectious illness among children aged 12–59 months. The study was situated in flood-affected

communities of Koto Tengah Subdistrict, Padang City, Indonesia, with data collection reported from January to May 2026. Because exposure and outcome data were assessed in the same survey, the design can estimate associations but cannot establish temporal sequence, disease incidence rates, or causality.

Study population and eligibility. The target population consisted of mothers or primary caregivers of children aged 12–59 months residing in selected flood-affected areas. Eligibility criteria reported in the source manuscript were residence in the area for at least 12 months, an eligible child, and provision of informed consent. Households with a child receiving inpatient care during data collection and records with incomplete study data were excluded. The unit of analysis was the child–household pair; the authors should confirm how households with more than one eligible child were handled.

Study-area selection and sampling. The study area was selected purposively on the basis of recurrent flooding, reportedly informed by BPBD and BNPB disaster records. Within selected communities, the source manuscript describes simple random selection from a household list. However, the number and names of selected neighborhoods, construction of an eligibility-based sampling frame, random selection procedure, numbers approached, refusals, and response rate were not documented. These details must be verified and added from field records before the sampling procedure can be described as reproducible or probability based.

Sample-size determination. A final sample of 152 child–caregiver pairs is reported. The source manuscript refers to a single-proportion (Lemeshow) calculation but omits the anticipated prevalence (p), confidence level (Z), absolute precision (d), source population size, and nonresponse adjustment. For a single-proportion calculation, $n_0 = Z^2 p(1-p)/d^2$, with any finite-population and nonresponse adjustments documented separately. The actual input parameters and resulting target sample size must be supplied from the research protocol; they cannot be reconstructed reliably from the final sample count alone.

Outcome measurement. The primary outcome was a binary composite of one or more reported episodes of diarrhea, acute respiratory infection (ARI), or skin disease in an eligible child during a prespecified recall window. The manuscript states “one to three months” without defining a consistent reference period, and illness ascertainment relied on caregiver symptoms or reported health-worker diagnoses. Before submission, the authors must specify a single recall period, case definitions for each disease, how physician-diagnosed and symptom-reported illness were distinguished, and whether overlapping or repeated episodes were counted once in the composite measure. In the absence of longitudinal follow-up, this outcome is referred to as reported illness history, not incidence.

Exposure and sanitation assessment. Household flood exposure was collected as frequency, duration, and water depth over the preceding 12 months and reported as high versus low. The precise score construction, units, cut-off, and source of any validated threshold were not available in the submitted manuscript and must be supplied from the original questionnaire. Sanitation indicators comprised latrine condition, solid-waste management, wastewater management, and access to clean water, informed by the Indonesian community-based total sanitation (STBM)



framework. Interviews were complemented by household observation of latrines, wastewater drainage and water sources. The manuscript reports both individual binary indicators and an overall sanitation category; operational criteria, component weights, and the composite threshold require documentation.

Covariates. Potential confounders described in the submitted analysis were maternal age (<30 versus ≥ 30 years), maternal education (low versus intermediate/high), maternal employment (employed versus not employed), child age (12–35 versus 36–59 months), and child nutritional status (normal versus abnormal). The anthropometric measure (e.g., weight-for-age, height-for-age, or weight-for-height), reference standard, and cut-offs used to determine nutritional status were not specified and need confirmation. These variables were treated as covariates, not presumed effect modifiers or mediators.

Data collection and quality control. Trained enumerators reportedly administered a structured questionnaire through household interviews and completed a sanitation observation checklist. The source manuscript states that item validity was evaluated using Pearson correlations and internal consistency with Cronbach's alpha. Yet the pilot sample size, item statistics, instrument version, alpha estimates, enumerator training procedures, and any data-entry checks are absent. These details should be reported only when original instruments and validation outputs can be verified. Self-reported symptoms and recalled flooding may introduce recall and classification error; no microbiological tests or water-quality measurements were described.

Statistical analysis. Descriptive variables were summarized as frequencies and percentages. Bivariate associations between each binary exposure and reported illness were examined using a chi-square test, with Fisher's exact test preferable when expected counts are small; crude odds ratios (ORs) and 95% confidence intervals (CIs) were reported. The manuscript describes a multivariable logistic regression with composite illness as the dependent variable and flood exposure, four sanitation components, maternal age, maternal education, maternal employment, child age, and nutritional status as predictors. Adjusted ORs (aORs), 95% CIs, and two-sided p values were reported; $p < 0.05$ was considered statistically significant. As only 56 outcome events are shown for approximately ten model predictors, coefficient stability and possible overfitting warrant evaluation. Before final reporting, the authors should verify the model specification, missing-data treatment, software/version, collinearity diagnostics, goodness of fit, and sensitivity analyses against the original analysis output. The summary table alone does not establish that these diagnostics were performed.

Ethical considerations. The submitted manuscript reports research ethics approval no. 266/EC-PKP/2026, informed consent, confidentiality of personal information, and freedom to withdraw without consequences for health care. The full name of the approving committee, issue date, and approval letter should be checked against institutional records before the article is submitted.

RESULTS

1. Characteristics of Respondents and Toddlers

Table 1. Characteristics of Respondents and Toddlers

Characteristics	Category	n	%
Mother's age	<30 years	87	57.2
	≥30 years	65	42.8
Mother's education	Low	46	30.3
	Intermediate/high	106	69.7
Mother's job	Doesn't work	103	67.8
	Work	49	32.2
Toddler age	12–35 months	78	51.3
	36–59 months	74	48.7
Nutritional status	Normal	111	73.0
	Abnormal	41	27.0

The majority of respondents were mothers aged <30 years with secondary/higher education and were unemployed. The age distribution of toddlers was relatively balanced, and most had normal nutritional status. These characteristics provide demographic and biological context for assessing the relationship between environmental exposures and infectious disease incidence.

2. Distribution of Flood Exposure, Environmental Sanitation, and Infectious Diseases

Table 2. Flood Exposure, Environmental Sanitation, and Infectious Diseases

Variables	Category	n	%
Flood exposure	Low	91	59.9
	High	61	40.1
Healthy toilet	Qualify	109	71.7
	Not eligible	43	28.3
Waste management	Good	96	63.2
	Not good	56	36.8
Wastewater management	Good	101	66.4
	Not good	51	33.6
Access to clean water	Adequate	114	75.0
	Inadequate	38	25.0
Environmental sanitation	Good	94	61.8
	Not good	58	38.2
Infectious diseases	Not experiencing	96	63.2
	Experience	56	36.8

More than a third of toddlers live in environments with high flood exposure and suboptimal sanitation. The most pressing issues are waste management, wastewater management, and inadequate access to sanitation. The proportion of infectious disease incidence indicates that more than a third of toddlers reportedly experienced at least one infectious disease during the observation



period. The underlying data source and verification status should be confirmed before these frequencies are presented as observed empirical results.

3. Relationship between Flood Exposure and Infectious Disease Incidence

Table 3. Flood Exposure with Infectious Disease Incidences

Flood exposure	Infectious diseases n (%)	Not sick n (%)	OR	95% CI	p-value
Low	24 (26.4)	67 (73.6)	1.00	Reference	—
High	32 (52.5)	29 (47.5)	3.08	1.54–6.16	<0.001

High flood exposure showed a positive association with infectious disease incidence. Toddlers in the high-exposure group had approximately three times the odds of disease incidence compared to the low-exposure group. The 95% CI range was above 1, and the p-value was <0.05, indicating that the association in the simulated data was statistically significant.

4. The Relationship between Environmental Sanitation and the Incidence of Infectious Diseases

Table 4. Relationship between Environmental Sanitation and Infectious Disease Incidence

Sanitation variables	Risk category: disease n (%)	Reference category: disease n (%)	OR	95% CI	p-value
Healthy toilet	23 (53.5)	33 (30.3)	2.65	1.26–5.58	0.009
Waste management	27 (48.2)	29 (30.2)	2.15	1.05–4.41	0.035
Wastewater management	25 (49.0)	31 (30.7)	2.17	1.06–4.45	0.033
Access to clean water	20 (52.6)	36 (31.6)	2.40	1.10–5.24	0.028
Overall sanitation	29 (50.0)	27 (28.7)	2.48	1.22–5.04	0.012

All sanitation components analyzed showed associations with infectious disease incidence in bivariate analysis. Substandard toilet conditions showed the largest association in crude OR, while overall environmental sanitation also showed an increased odds of disease in the group with poor sanitation conditions. These findings indicate that disease risk is not solely related to a single sanitation component but may arise from a combination of multiple environmental exposure pathways.

5. Multiple Logistic Regression Analysis

The multivariate model included flood exposure, sanitation components, and maternal and toddler characteristics as candidate variables.

Table 5. Multiple Logistic Regression Analysis

Variables	p-value	Adjusted OR	95% CI
High flood exposure	0.007	2.48	1.27–4.85
The toilet does not meet the requirements	0.064	1.88	0.96–3.68
Poor waste management	0.134	1.62	0.86–3.05

Poor wastewater management	0.096	1.73	0.90–3.34
Inadequate access to clean water	0.083	1.80	0.93–3.48
Maternal age ≥ 30 years	0.527	1.21	0.67–2.18
Low education	0.348	1.36	0.71–2.62
Working mother	0.603	1.17	0.64–2.15
Toddlers aged 12–35 months	0.162	1.52	0.84–2.76
Abnormal nutritional status	0.046	1.89	1.01–3.54

After simultaneously controlling for maternal characteristics, toddler age, nutritional status, and sanitation components, High flood exposure continued to show an independent association with infectious disease incidence. Toddlers with high flood exposure had approximately 2.5 times the odds of disease compared to toddlers with low exposure. Abnormal nutritional status also maintained a statistical association with disease incidence, although the magnitude of the association was lower. Meanwhile, individual sanitation components no longer reached statistical significance after being included simultaneously in the model, indicating a possible interrelationship between sanitation components and the contribution of flood exposure to overall risk.

DISCUSSION

The manuscript reports infectious illness in 56/152 children (36.8%). In the unadjusted analysis, 32/61 children (52.5%) in the high-flood-exposure group and 24/91 (26.4%) in the low-exposure group had an illness history. The reported adjusted association for high flood exposure was aOR 2.48 (95% CI 1.27–4.85; $p = 0.007$). Abnormal nutritional status was also associated with reported illness (aOR 1.89; 95% CI 1.01–3.54; $p = 0.046$). The reported odds ratios represent associations with prevalent/recalled illness rather than prospective disease risk; they should not be interpreted as causal effects. Individual sanitation indicators had positive unadjusted associations but their 95% confidence intervals included the null after adjustment.

Several pathways could plausibly connect flooding with infections: contact with contaminated water, disruption of sanitation facilities, crowding and damp indoor environments, and reduced access to safe water and hygiene. These mechanisms were not directly measured in this study. The combined outcome of diarrhea, ARI and skin disease also represents conditions with distinct etiologies and transmission routes, so the pooled association cannot be assumed to apply equally to each condition. Future analyses should disaggregate outcomes if sample sizes permit.

The findings are broadly consistent with published evidence linking flooding or rainfall anomalies to childhood infectious morbidity (Dimitrova et al., 2022; Wang et al., 2023). Saha et al. (2024) also examined repeated flooding and diarrhea among rural Indian children, while Yirdaw et al. (2025) reported sanitation-related correlates of diarrhea in a flood-affected Ethiopian setting. These comparisons provide epidemiological context but should be interpreted cautiously because exposure definitions, outcome ascertainment, background WASH conditions and population characteristics differ. In particular, adjusted odds ratios are not directly comparable without considering study design and covariate adjustment.



The attenuation of sanitation associations in the multivariable model has several possible explanations, including overlapping household exposures, confounding, limited precision, and correlations among the sanitation measures. It does not demonstrate that sanitation is unimportant or that flood exposure mediates its effects. A multicollinearity diagnosis (such as variance inflation factors), comparison of nested models and examination of correlations among indicators would be needed to evaluate these possibilities. Kikuchi (2023) also highlights the complexity of sanitation effects in flood-prone settings, where the resilience of facilities may matter in addition to their nominal type.

Study limitations. The cross-sectional design cannot establish whether a reported illness followed the measured flood exposure. A caregiver-reported, heterogeneous illness outcome may be affected by recall bias and case misclassification, especially because the recall period is not consistently defined. Purposive selection of affected areas and incomplete documentation of household randomization limit external validity and reproducibility. The small number of illness events relative to the number of model parameters may yield unstable adjusted estimates; the available manuscript does not show diagnostics or sensitivity analyses. The survey also lacks direct microbiological measurements, socioeconomic variables such as income, and a prospective flood-event timeline. Finally, the manuscript uses the phrase 'simulated data' in its Results section; unless primary data and analytic outputs are verified, all numerical results must be identified as illustrative, not empirical findings.

Implications. If verified against original records, the observed pattern would justify evaluating integrated public-health measures that combine flood preparedness, protection of household water and sanitation services, and nutritional support. Such measures are reasonable practice considerations, but their effectiveness cannot be inferred from the present cross-sectional associations. Longitudinal and event-based research with documented exposure timing, clearly defined disease outcomes and model diagnostics is needed.

CONCLUSIONS

Among the 152 observations presented, reported infectious illness was more common in the high-flood-exposure group than in the low-exposure group. The manuscript reports an association for high flood exposure after covariate adjustment (aOR 2.48; 95% CI 1.27–4.85), along with an association for abnormal nutritional status (aOR 1.89; 95% CI 1.01–3.54). Individual sanitation indicators were associated with illness in unadjusted comparisons but were not statistically distinguishable from the null after adjustment. These are observational associations, and their validity depends on confirmation of the underlying dataset and analytic procedures.

The findings support further investigation of how household flood exposure, WASH conditions and child nutrition jointly relate to illness in flood-prone communities. They do not establish that climate change caused the observed illnesses or that flooding independently caused disease. Methodological priorities for follow-up work include standardized case definitions, a consistent recall interval, prespecified exposure cut-offs, transparent sampling, and appropriately powered multivariable analyses.

For practice, local public-health and disaster-management agencies may consider coordinated protection of household drinking water, sanitation and child nutrition during flood preparedness and response. Any specific intervention should be evaluated using longitudinal surveillance or an appropriate intervention design rather than inferred solely from this survey.

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