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Research Article

THE RELATIONSHIP BETWEEN CLIMATE VARIABILITY AND INFANT DIARRHEA IN A COASTAL AREA OF JAKARTA

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Abstract
This study examines climatic patterns and the delayed relationship between climate factors and diarrheal cases in this age group. This ecological panel study uses secondary data on monthly diarrhea cases in Penjaringan Subdistrict, North Jakarta, Indonesia. Diarrhea cases obtained from the DKI Jakarta Provincial Health Office between 2013 and 2024 (144 months). Climate factors included temperature, rainfall, relative humidity, and El Niño–Southern Oscillation (ENSO) index. The analysis of climatic patterns was examined descriptively. Associations were analyzed using a negative binomial mixed-effects model with distributed lags to account for delayed effects and spatial heterogeneity. The results indicate that infant diarrhea cases varied significantly by season. An increase of 1°C in temperature at lag 1 increased the case rate by 35% (IRR = 1.35; p = 0.038). Rainfall at lags 0 and 1 showed a small but substantial positive relationship with diarrhea. Higher relative humidity was associated with a lower risk, while ENSO conditions were positively associated with diarrhea. The study found that local meteorological conditions and large-scale climate variability influence the incidence of infant diarrhea in coastal areas. The novelty of this study lies in integrating a distributed lag model with ENSO effects on vulnerable populations. These findings support the development of climate-sensitive monitoring and early warning systems, and strengthening water, sanitation, and hygiene interventions during periods of high climate risk may help reduce the burden of diarrheal disease among high-risk groups.

Keywords: Climate, Diarrhea, Infant, Seasons, Time Series Analysis.

INTRODUCTION

Diarrhea remains a major public health challenge in low-to middle-income countries. It is also prevalent in tropical cities experiencing rapid urbanization, with inadequate housing and environmental pollution (Troeger et al., 2020; Geremew et al., 2024; Hossain et al., 2024). In children aged 1-59 months, diarrhea is the third greatest cause of death, and approximately 1.7 billion episodes of diarrhea occur annually (WHO, 2017). Young children are the most vulnerable in Southeast Asia, including in Indonesia (Aik et al., 2020; Dharmayanti et al., 2022). Climate variations and seasonal patterns are both factors influencing the spread of this disease.

Several studies have shown that climate variability, such as rainfall, temperature, and relative humidity, as well as global climate phenomena, particularly the El Niño–Southern Oscillation (ENSO), can influence the transmission patterns of diarrhea (Adams et al., 2022; Dhimal et al., 2022). Research shows that climate factors can reduce water quality, disrupt sanitation systems, and influence pathogen reproduction (Geremew et al., 2024). However, the relationship between climate factors and ENSO on diarrhea can vary between months and even seasons. Numerous studies show that climate factors not only trigger diarrhea directly but can also have medium/long-term effects through biological (pathogen growth) and environmental (water, sanitation, flooding/drought) changes (Malik et al., 2021; Geremew et al., 2024; Hossain et al., 2024).

In epidemiological research, studies related to climate and disease often use a simple lag structure or a single-lag model. However, these models may fail to capture the cumulative and delayed effects of climate on disease incidence (Rahaman et al., 2023; Pan et al., 2025). Literature reviews have shown a relationship between high temperatures, rainfall, and diarrhea. Disease outbreaks often occur in areas with inadequate water and sanitation conditions (Zhang et al., 2024; Gobena & Mengistu, 2025). In urban areas, further research is needed to determine whether the effects of climate on diarrhea are immediate, delayed, or a shift in their spread pattern (Geremew et al., 2024).

Environments and communities can vary widely within cities (Alfiansyah et al., 2023). Access to water, toilet facilities, and health services exists in some locations. While others are densely populated and characterized by poor conditions and high vulnerability due to poor economic conditions (Huynh et al., 2024; Rizki et al., 2025). Previous research has shown that studies in urban or city level often obscure the relationship between climate and health at the individual level. Thus, this information can be used to design community adaptations for vulnerable groups and early warning systems (Horn et al., 2018). Research using panel data would be particularly useful for addressing differences across locations and time periods. Understanding the delayed effects of climate requires the use of distributed lag models to examine the relationship between climate and diarrhea (Haque et al., 2024).

Several studies have linked meteorological factors to diarrheal disease, but significant gaps remain in the literature (Adeboyejo et al., 2020; Deshpande et al., 2020; Kraay et al., 2020). While urban areas are highly vulnerable to climate variability, population density, and recurrent flooding, empirical evidence from coastal urban environments in Indonesia remains limited. Many studies focus on the direct effects of climate factors without adequately examining lagged associations, leaving the temporal dynamics of disease risk incompletely understood (Bhandari et al., 2020; Haque et al., 2024). Large-scale climate variability, such as ENSO, is rarely included in analyses, particularly for infants, as the most vulnerable population group. This gap limits the development of local early warning systems.

In Jakarta's coastal districts, high population density, seasonal flooding, and environmental exposures can amplify pathways of diarrheal disease transmission. However, the magnitude of climate factors' influence on infant diarrhea incidence in these areas remains unclear. This uncertainty limits the development of climate-based early warning systems and targeted public health interventions (WHO, 2021). To address these gaps, this study aims to examine seasonal patterns of diarrhea incidence in infants in an urban coastal area and analyze the lagged associations between temperature, rainfall, humidity, and ENSO with diarrhea cases.

This study used a negative binomial mixed-effects model with distributed lags at the urban village level. This model evaluated the direct and delayed effects of climate factors on diarrhea cases across distinct regions (Phung et al., 2015; Haque et al., 2024). The advantage of this method is its ability to capture changes in disease patterns across time. However, its application in health research remains limited, particularly in densely populated cities (Hajat et al., 2022). Compare againts conventional methods, such as single-lag or moving-average models, the distributed lag model can capture the effects of climate that appear at different time lags. Previous research has shown that this model is more accurate and easier to interpret to understand diarrhea risk (Fang et al., 2020; Yeh et al., 2025). Other studies point out the need to strengthen health monitoring systems and establish climate-based early warning systems (Haque et al., 2024).

This study contributes to the development of climate-sensitive research in coastal tropical areas by integrating distributed lag modeling and large-scale climate variability indicators in the infant population. These findings are expected to strengthen climate-based health surveillance systems and support the development of early warning systems and adaptive water, sanitation, and hygiene (WASH) interventions for vulnerable populations. This study provides novel evidence through the integration of distributed lag modeling and ENSO indicators at the urban village level in a high-density coastal setting.

RESEARCH METHOD

This study is an ecological panel design using secondary surveillance data. Data on diarrhea cases among children aged 0-11 months were obtained from the DKI Jakarta Provincial Health Office's routine surveillance platform. The focus was on the monthly cases of reported diarrhea among infants in five urban villages in Penjaringan District, North Jakarta, Indonesia. The data was collected from January 2013 to December 2024, yielding 144 monthly observations across five urban villages. The case definition follows national standards aligned with the World Health Organization (WHO) diarrhea criteria, namely three or more watery stools in one day (WHO, 2017). Climate data were obtained from the Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG). The climate variables used include: (1) monthly average temperature (°C), calculated as the arithmetic mean of all daily observations; (2) total monthly rainfall (mm), calculated by summing daily rainfall to capture cumulative water availability; (3) monthly relative humidity (%), accumulated and then averaged to obtain a monthly value. The data was sourced from the Tanjung Priok Meteorological Station. Lastly, (4) El Niño–Southern Oscillation (ENSO), a climate phenomenon that affects the tropical Pacific Ocean, is measured using the Oceanic Niño Index (ONI), which is the three- month average of sea surface temperature anomalies in the Niño 3.4 region.

The data analysis began with descriptive statistics that summarized monthly diarrhea cases and climate variables from January 2013 to December 2024. Monthly distribution patterns over the study period illustrated seasonal trends in diarrhea cases. The dataset comprised monthly observations from five urban villages, yielding a total of 720 panel observations. As the count data exhibited excessive dispersion and clustering within the urban villages, a mixed-effects negative binomial regression model with a random intercept for each urban village was used (Bolker et al., 2009). The fixed effect's structure included a distributed lag of 0–3 months for temperature and rainfall, determined a priori based on biological plausibility (Yadav, 2026). Relative humidity and ENSO were included as exposures at lag 0 due to their more stable temporal patterns, as well as to avoid model over-parameterization (Hanifa & Wiratmo, 2024). Associations were reported as incidence rate ratios (IRRs) with 95% confidence intervals. Lag effects were visualised using lag-specific response curves for temperature and rainfall from the final model. Variance inflation factors (VIFs) were used to examine multicollinearity. The average VIF score is 3, indicating no serious multicollinearity (Daoud, 2017). Sensitivity analyses developed alternative modelling techniques, including generalized estimating equations and fixed-effects negative binomial models (M. Wang, 2014). All analyses were conducted using Stata 17.0 with robust standard errors. With 720 panel observations and $\alpha = 0.05$, this study has sufficient statistical power (>80%) to detect a moderate effect size (IRR ≥ 1.20–1.30) in a negative binomial regression model (Hardin & Hilbe, 2014; Phuangrach & Sarakarn, 2023). The distributed lag specification increases the model parameters, but remains within acceptable limits given the available degrees of freedom. Because the dataset comprises case reports from the study area's population, the analysis reflects population-level associations, further strengthening the inferential reliability (Karuppusami et al., 2026).

The study protocol was reviewed and approved by the Research Ethics Committee of the School of Environmental Science, University of Indonesia (No. KET-059/UN2.F13.D1.KE1/PPM.00/2025). All analyses were conducted using anonymized secondary data, and informed consent was waived in accordance with the institution's guidelines.

RESULTS AND DISCUSSION

Disease and Seasonal Patterns of Infant Diarrhea

During the study period, 6,709 cases of diarrhoea among infants aged 0 to 11 months were reported in five urban villages in Penjaringan District. Most villages recorded a small number of cases each month, with a mean of 9 and a median of 4, as shown in Table 1. The average monthly temperature was 28.7°C, with a range from 26.9°C to 30.6°C. Monthly rainfall exhibited greater variability, averaging 169.5 mm, and ranging from 0 mm to 963 mm. The average humidity was 76.9%, with values ranging from 66.8% to 85.3%. The Oceanic Niño Index (ONI) ranged from -1.3, representing a strong La Niña event, to +2.6, representing a strong El Niño event.

Table 1. Distribution of Monthly Climatic and Health of Study Variables (2013–2024)

Variables	Number of months	Mean	Standard deviation	Minimum	P25	Median	P75	Maximum	Iqr
Diarrhea cases	144	9.3	13.2	0	1	4	12	81	11
Mean temperature (°C)	144	28.7	0.6	26.9	28.4	28.8	29.2	30.6	0.8
Rainfall (mm)	144	169.5	176.5	0	52.8	117.5	215.8	963.3	163
Relative humidity (%)	144	76.9	4.1	66.8	74	76.76	80.1	85.3	6.1
ENSO	144	0.1	0.9	-1.3	-0.6	-0.1	0.5	2.6	1.1

Note: P25 = 25th percentile; P75 = 75th percentile; Iqr = interquartile range (P75 – P25)

According to Figure 1A, the temporal trend shows a small increase in diarrhea cases in recent years. While most research periods have observed a gradual decline in cases. Furthermore, there is heterogeneity of diarrhea cases among the urban villages, with average monthly cases ranging from 2.6 to 22.1 across the five regions (Figure 1B). The observed variance-to-mean ratio is 18.8, indicating a considerable degree of overdispersion. This value is higher than the predicted values of 1.0 for a Poisson distribution. Several factors, such as clustering effect, the possibility of other unreported factors, and the dynamics of disease transmission, can contribute to this variation.

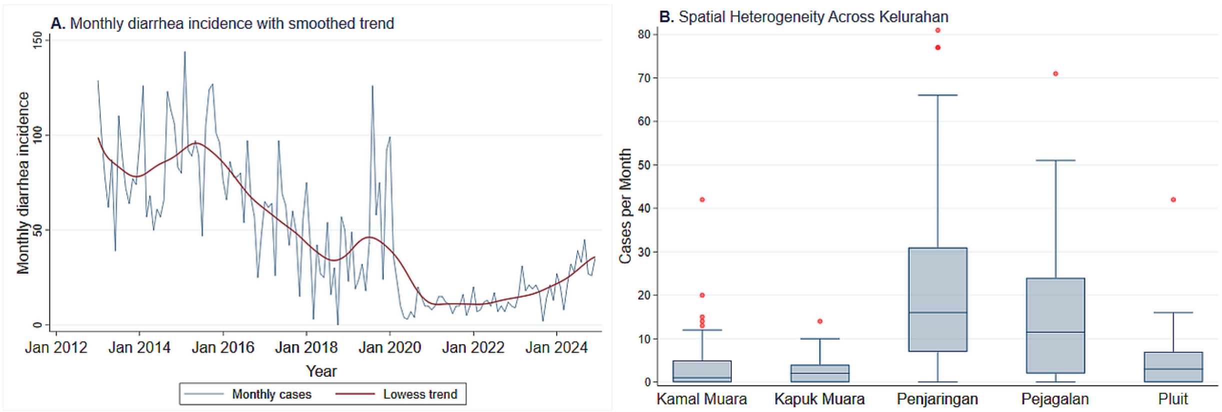

Figure 1. Diarrhea case distribution and regional heterogeneity

Note: Panel A displays a LOWESS-smoothed trend in addition to monthly diarrhea cases. Panel B shows the variations within urban villages by displaying the distribution of cases among them.

A descriptive time-series visualization was performed to identify the seasonal patterns (Figure 2). Monthly diarrhea cases increase around the end of the dry season (August–October), decrease in the middle of the year, with a peak in the early months (January–February). More diarrhea cases are seen in Panel A during the period of less rainfall, especially from March to June. A rise in mild episodes of diarrhea is correlated with a bimodal seasonal pattern in temperature, which peaks around May and October. Panel B demonstrates that increased relative humidity is linked to lower cases of diarrhea. Seasonal variations in ENSO are consistent with the pattern of diarrheal cases, indicating the possible impact of large-scale climate variability. The observed seasonal fluctuations in infant diarrheal cases suggest a potential influence of climatic factors, warranting further investigation using a mixed-effects negative binomial model. These descriptive findings suggest a temporal alignment between climate variability and diarrhea incidence. This supports further inferential analysis using distributed lag modeling.

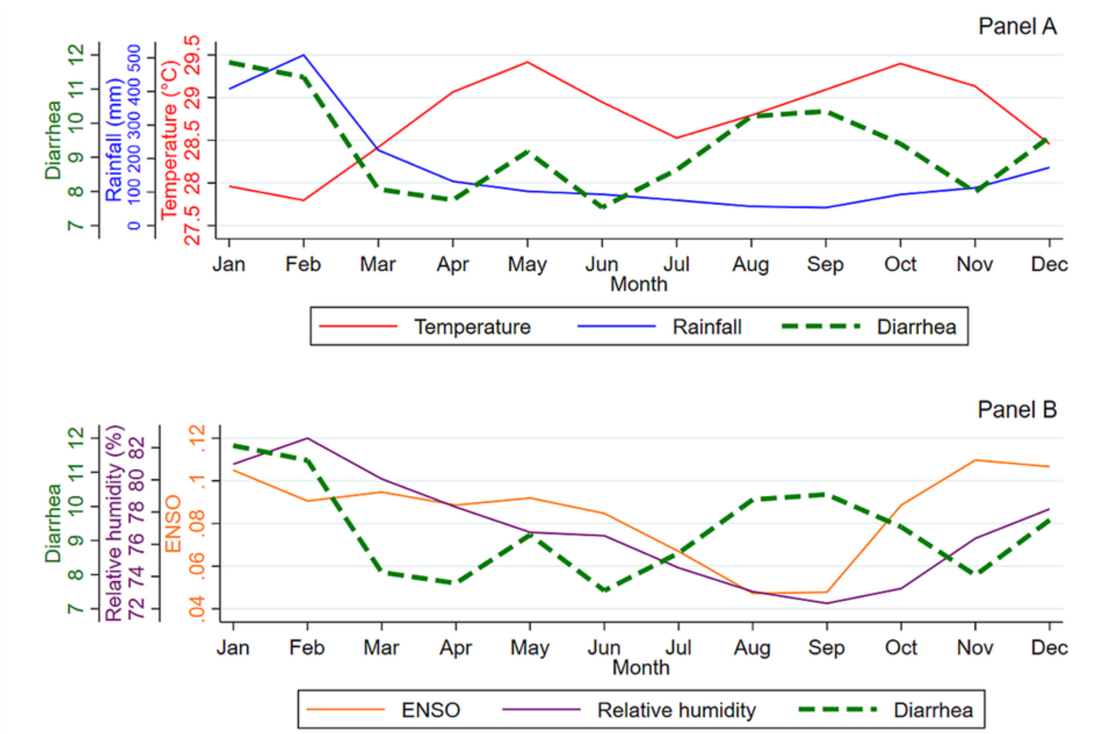

Figure 2. Seasonal variation in the cases of diarrhea and 12-year monthly averages of climate variables
Note: Diarrhea cases are shown as the green dotted line in both panels. All values represent 12-year monthly averages.

Association Between Climate Variability and Infant Diarrhea

The associations between climate variables and monthly cases of diarrhea were examined using a mixed-effects negative binomial regression model with distributed lags. As shown in Table 2, a negative correlation is evident between temperature at lag 0 and infant diarrhea. This finding shows a 47% decrease in cases per 1°C increase in temperature (IRR = 0.53; $p < 0.001$). In contrast, there is a delayed reaction in the opposite direction. A 1°C increase in temperature at lag 1 is associated with a 35% increase in cases (IRR = 1.35; $p = 0.038$). Rainfall at lag 0 and lag 1 exhibited a modest but statistically significant positive correlation with diarrhea (IRR = 1.002; $p < 0.001$ and IRR = 1.001; $p = 0.045$). A positive correlation was identified between higher relative humidity and a reduced risk, with an incidence rate ratio (IRR = 0.845; $p < 0.001$). ENSO conditions were positively associated with diarrhea cases (IRR = 1.41; $p < 0.001$), indicating an increased risk during El Niño periods. The results support the hypothesis that both local weather conditions and larger climate patterns influence the incidence of infant diarrhea in urban coastal areas. Both immediate and delayed effects were observed. These findings address the research objective by demonstrating that local meteorological factors and large-scale climate changes significantly impact the rates of infant diarrhea.

As shown in Table 2, a lag-dependent relationship exists between climate variables and diarrhea in infants, with temperature and the ENSO index being the most influential predictors. The results show that diarrhea in urban coastal settings is influenced by climate variability, both immediate and delayed effects. This study considers the unique effect of temperature on diarrhea. This phenomenon is characterized by an inverse relationship at lag 0 followed by a positive association at lag 1. These results show that temperature can influence diarrhea through both direct and delayed pathways. The positive relationship between diarrhea and ENSO further supports the role of global climate anomalies in shaping disease distribution patterns within a region. Meanwhile, rainfall shows a weaker, inverse relationship at longer lags. These results reflect that rainfall can act as an environmental buffer. This means that rainfall is a natural factor that helps balance or reduce health risks in dense urban areas. These results show that incorporating lag-sensitive climate factors can improve understanding and predict diarrheal disease patterns in city settings (Wang et al., 2022; Lee et al., 2023).

Table 2. Associations between climate variables and diarrheal cases estimated using mixed-effects negative binomial models

Variables	Mixed effects-NB	95% CI	*p* - value
Temperature Lag (0)	0.526	0.419 - 0.660	< 0.001
Temperature Lag (1)	1.350	1.016 - 1.792	0.038
Temperature Lag (2)	0.960	0.729 - 1.265	0.772
Temperature Lag (3)	0.943	0.756 - 1.175	0.600
Rainfall Lag 0	1.002	1.001 - 1.003	< 0.001
Rainfall Lag (1)	1.001	1.000 - 1.002	0.045
Rainfall Lag (2)	1.000	0.999 - 1.001	0.436
Rainfall Lag (3)	1.001	0.999 - 1.001	0.052
Relative humidity Lag (0)	0.845	0.818 - 0.874	< 0.001
ENSO Lag (0)	1.408	1.270 - 1.560	< 0.001
AIC	4045.56		
BIC	4104.82		

Note: IRR = Cases Rate Ratio from mixed-effects negative binomial regression; 95% CI = 95% confidence intervals; Temperature effects per 1°C increase; Rainfall effects per 1mm increase; Model includes random intercepts for urban village.

These findings align with recent literature indicating that temperature and large-scale climate variability influence diarrhea cases, while the relationship between rainfall and diarrhea is highly context-dependent. Studies at the national and subnational levels have reported a positive correlation between rising temperatures and increased diarrhea cases, consistent with the short-term temperature effects observed in this study (Delahoy et al., 2021; Lee et al., 2023). Research on ENSO also indicates that El Niño and La Niña phases are associated with fluctuations in enteric diseases, driven by changes in regional rainfall patterns and temperatures. The positive relationship between ENSO and diarrhea cases in this study supports the earlier findings. The results suggest that ENSO anomalies may increase the prevalence of digestive illnesses in tropical cities (Heaney et al., 2019; Adams et al., 2022).

There are regional differences in the relationship between rainfall and diarrhea. Some studies report an increase in cases following heavy rain or flooding due to contamination of water sources (Lan et al., 2022; P. Wang et al., 2023). Conversely, other studies have found an increase in cases during dry periods, when water scarcity may concentrate exposure pathways (Adams et al., 2022; P. Wang et al., 2022). The weaker or inverse associations at longer lags in this study are consistent with the latest multi-site synthesis, which emphasises that the direction and timing of rainfall effects are influenced by local hydrology, WASH conditions, and pathogen ecology (Mengistie et al., 2022; Grembi et al., 2024). This research also found an inverse relationship between relative humidity and diarrhea cases. These results are consistent with laboratory and field studies showing that some enteric pathogens survive or transmit more effectively under lower humidity and temperature conditions (Chua et al., 2021; Dharmayanti et al., 2022). Previous epidemiological analyses have also shown that atmospheric moisture can influence diarrhea transmission in specific environments.

The evidence suggests that the effects of climate variability on infant diarrhea are shaped by both immediate and delayed responses. Figure 3 shows the lag effects, focusing on rainfall and temperature.

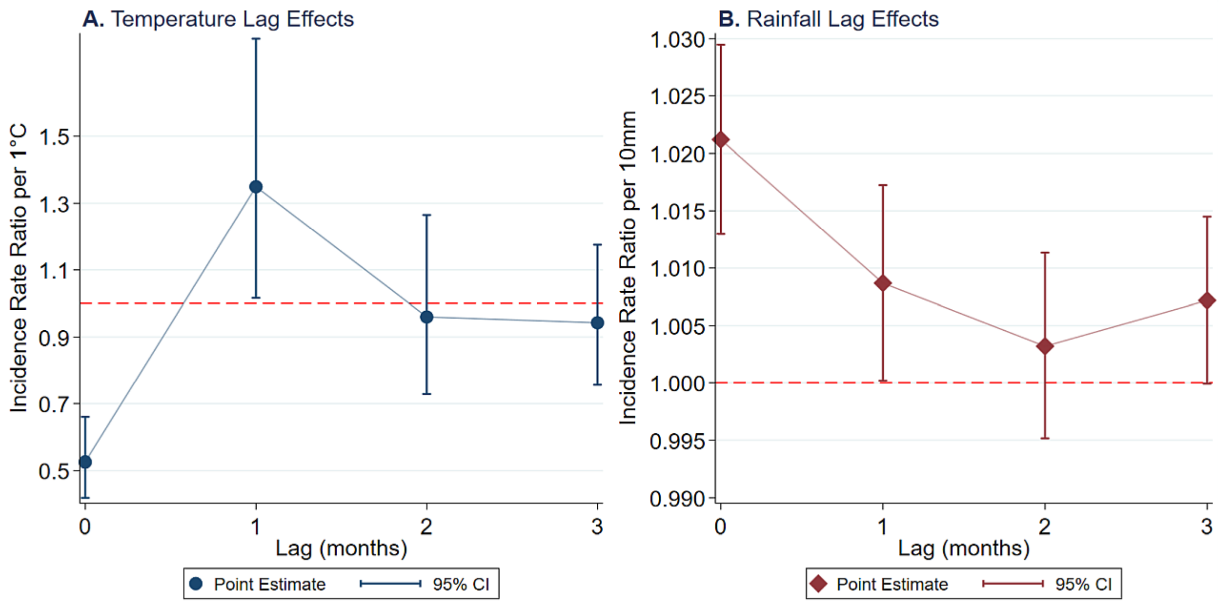

Figure 3. Lag-Specific Climate Effects

Note: Panel A displays the lag effect of temperature at a 0–3 month period, and Panel B displays the lag effect of rainfall at a 0–3 month period. The plot diagram shows the case rate ratio (IRR) with 95% confidence intervals. Points represent IRR values, horizontal lines represent 95% CIs, and the vertical dashed line represents an IRR of 1.0. For a more general interpretation, the exposure-response values in panel B are increased by 10 mm of rainfall. The regression coefficients in Table 2 are on a 1-mm scale.

Figure 3 shows the delayed effect of temperature and diarrhea in infants as shown in the final model. The direction of the temperature effect depends on the lag period. Panel A shows a negative association at lag 0, while a positive association is seen at lag 1. These results show that the effect of temperature on disease transmission can be delayed. Conversely, rainfall shows a positive direct effect at lag 0, which appears to weaken at subsequent lags. Thus, the direct effect of rainfall is statistically significant, while subsequent delayed effects decrease and become insignificant.

The results suggest an association between climate factors and diarrhea in infants aged 0 to 11 months. These data are biologically relevant because this age group is highly susceptible to gastrointestinal infections. The immune system and gut microbiota of infants are still developing, and their digestive enzymes are not yet operating efficiently. These factors make infants more susceptible to diarrhea-causing pathogens (Kotloff, 2017; Troeger et al., 2020). Infants are also highly dependent on the quality of their immediate environment. Improving environmental cleanliness, including caregivers' and mothers' personal hygiene, can improve infant health and limit exposure to climate-sensitive disease transmission (Levy et al., 2018). Moreover, exclusive breastfeeding and adequate nutrition have been shown to reduce the risk of diarrhea (WHO, 2017; Paulos et al., 2025).

According to the study, high temperatures can accelerate pathogen replication and food spoilage (Martín-Miguélez et al., 2025). Extreme temperatures can also increase water usage, concentrate contamination sources, and influence the behavior of disease vectors (Alqassim, 2025). The presence of ENSO anomalies can worsen disease transmission pathways by combining severe temperatures and rainfall. Conversely, heavy rainfall can reduce contaminant levels, but in other areas, it can pollute water supplies (Deshpande et al., 2020). The research indicates that WASH interventions must be adapted to climate and ENSO conditions to prevent and control disease transmission (Adams et al., 2022).

The model's robustness was further assessed through sensitivity analyses using alternative models. The results were consistent with the main model in both direction and magnitude. Like the primary model, temperature, rainfall, relative humidity, and ENSO remained significant at lag 0. The sensitivity analysis results show that the observed associations are stable across multiple model variations. Diagnostic analysis of prediction errors was performed to assess whether the model adequately explains the data and produces dependable predictions. The diagnostic test results showed adequate fit between measured and predicted diarrhea cases (MAE = 5.6 cases; RMSE = 9.1 cases). These diagnostic results point out the need to account for overdispersion and clustering in health and climate data analysis (Perreault et al., 2024). This study underscores the importance of accounting for time lags in climate factors to anticipate patterns of diarrheal disease distribution in metropolitan cities.

This research provides valuable insights in several important ways. It uses a longitudinal design, including a lag model that allows it to estimate immediate and delayed climate effects while accounting for inter-village differences. The study also integrates ENSO into infant diarrhea. This approach is rarely implemented in densely populated coastal cities in Southeast Asia. By focusing on infants aged 0–11 months, the study provides specific evidence on the relationship between climate (temperature, rainfall, relative humidity) and ENSO and diarrhea cases in a vulnerable population. This group is often underrepresented in the scientific literature on the effects of climate change on health.

This study provides new evidence on the dynamic relationship between climate and health among vulnerable populations by combining panel data analysis with indicators of climate variability. The difference between immediate and delayed temperature effects suggests that risk assessment models should use distributed lag structures rather than single-lag assumptions. These findings advance methodological approaches in climate-sensitive epidemiology. Although conducted in a specific coastal district, the findings may be relevant to other densely populated tropical coastal cities. The climate–diarrhea mechanisms observed are likely applicable to similar urban environments with vulnerable infant populations.

This study has several limitations. First, the use of aggregate urban village data cannot directly infer causality among individuals. Furthermore, the results are not entirely unbiased because residual confounding factors, namely socioeconomic and WASH conditions, have not been included. Second, the results are largely determined by the regular health monitoring system. The quality of reported data can be affected by data completeness, recording accuracy, and the capacity of the surveillance system in each urban village. Third, the use of aggregate data can mask short-term extreme climate events and disease patterns. Meanwhile, the absence of pathogen data may limit the analysis's ability to identify pathogens involved in the study. Finally, although diagnostic tests and model sensitivity support the main model, the predictive factors (MAE/RMSE) only measure model adequacy and cannot be used directly for forecasting. Nevertheless, the relationship between climate and diarrhea is consistent with prior knowledge and contributes to the validity of this study.

The findings are consistent with the etiological hypothesis that climate variability influences gastrointestinal infections in infants. Variations in climatic factors (temperature, humidity, and rainfall) and global climate variables (ENSO) reveal the complex link between climate and health in urban coastal environments. This study improves methods for studying health and climate by considering delayed effects over time and providing specific insights from a crowded tropical region (Geremew et al., 2024; P. Wang et al., 2022). These results underscore the need to include climate indicators and ENSO in public health risk assessments. Strengthening WASH infrastructure and implementing community-based surveillance may help mitigate the disease burden in vulnerable infant populations.

The integration of rainfall and ENSO indicators into routine disease monitoring may enhance early warning systems. The findings underscore the need to integrate climate indicators into routine health surveillance. Early warning systems incorporating rainfall and ENSO forecasts may help predict diarrhea outbreaks among infants in coastal cities. In the future, research should include individual-level data and sanitation measures to better understand how climate influences diarrhea.

CONCLUSION

This study shows a significant association between diarrhea cases among children aged 0-11 months and local weather and larger climate patterns (ENSO) in urban coastal areas, with immediate and delayed effects on temperature and rainfall. Using a mixed-effects approach integrated with distributed lags allows the analysis to capture both short-term and delayed climate influences. This approach also accounts for community clustering at the urban village level. The study's results underscore the need to incorporate climate indicators into health surveillance systems. Incorporating rainfall and ENSO indicators into routine monitoring could improve the capacity to respond proactively. The study also stresses the importance of disease prevention methods that are sensitive to climate factors to safeguard those most at risk. Improving WASH facilities and public health monitoring systems is the most effective strategy to reduce the impact of diarrhea. Prospective research should collect pathogen data to understand the mechanisms underlying disease spread and to provide evidence for the development of more targeted health interventions.

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AUTHOR CONTRIBUTIONS

Conceptualization and methodology, I.D.; Software, D.H.T.; Validation, R.P. and T.E.B.S.; Formal Analysis, I.D.; Investigation, D.H.T.; Resources and data curation, I.D.; Writing – Original Draft Preparation, I.D and D.H.T.; Writing – Review & Editing, I.D, R.P., D.H.T., and T.E.B.S.; Visualization, I.D.; Supervision, R.P., D.H.T., and T.E.B.S; Project Administration, I.D; Funding Acquisition, none.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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