



## Analysis of the Relationship between Waste Management Systems and Dengue Fever Cases

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### Abstract

Dengue fever remains a major public health challenge in rapidly urbanizing tropical regions, where environmental conditions significantly influence disease transmission. This study aims to examine the relationship between urban waste management systems and dengue fever incidence in Jakarta, Surabaya, and Bandung during the 2018–2023 period. A sequential explanatory mixed-methods approach was employed, integrating epidemiological data, waste management indicators, spatial analysis, field observations, and stakeholder interviews. The findings reveal that waste collection frequency and municipal service coverage are negatively associated with dengue incidence, whereas ineffective waste segregation contributes to increased mosquito breeding opportunities. Spatial analysis identifies significant clustering of dengue cases in areas characterized by waste accumulation and inadequate environmental infrastructure. The findings highlight the importance of combining waste management, community participation, and institutional coordination to strengthen dengue prevention. These results provide practical guidance for urban policymakers seeking sustainable and environmentally informed public health interventions.

## INTRODUCTION

Dengue fever remains one of the most rapidly expanding vector-borne diseases worldwide, posing substantial public health, economic, and environmental challenges, particularly in tropical and subtropical urban regions. According to the World Health Organization, the global incidence of dengue has increased dramatically over the past two decades, with urbanization, climate variability, population growth, and environmental degradation identified as major drivers of transmission (Gibb et al., 2023; Nakase et al., 2024; Zhang, 2024). Southeast Asia continues to experience recurrent dengue outbreaks, and Indonesia consistently ranks among the countries reporting the highest disease burden in the region. Major metropolitan areas such as Jakarta, Surabaya, and Bandung frequently experience seasonal surges in dengue cases, creating significant pressure on healthcare systems and urban governance institutions (Rania & Junaid, 2025; Waskito et al., 2025; Haryanto et al., 2025).

Recent scholarship has increasingly emphasized that dengue transmission is not solely determined by climatic conditions but is also strongly influenced by urban environmental management. The rapid expansion of densely populated settlements, inadequate sanitation services, uncontrolled waste generation, and ineffective environmental governance have contributed to the proliferation of *Aedes aegypti* breeding habitats (da Silva & Scalize, 2023; Abdullah et al., 2024; Abbasi, 2025). Studies have demonstrated that discarded containers, plastic waste, used tires, and unmanaged refuse can accumulate rainwater and create favorable conditions for mosquito reproduction. Consequently, urban waste management has emerged as an important environmental determinant of dengue transmission and a critical component of sustainable disease prevention strategies (Mahmud et al., 2023; Abdullah et al., 2024; Alqassim, 2024).

The relationship between waste management and dengue has attracted growing attention within environmental health and urban sustainability research. Recent systematic reviews indicate that ineffective solid waste management contributes significantly to the persistence of mosquito breeding sites and increases the risk of vector-borne disease outbreaks. Environmental conditions characterized by irregular waste collection, low recycling rates, poor drainage systems, and inadequate municipal service coverage have been associated with higher mosquito density and increased dengue incidence (Olagunju, 2023; Yani, 2024). These findings support the broader One Health perspective, which recognizes the interconnectedness of environmental quality, human health, and urban governance in addressing complex public health challenges (Roy et al., 2025; Mumford et al., 2023; Danasekaran, 2024; Izah et al., 2024; Murray et al., 2022).

Current evidence suggests that waste accumulation affects dengue transmission through multiple mechanisms. First, improperly managed waste provides artificial water-holding containers that facilitate mosquito breeding. Second, inadequate waste disposal often coincides with poor drainage infrastructure, resulting in stagnant water accumulation. Third, neighborhoods characterized by weak municipal services frequently experience overlapping environmental vulnerabilities that intensify disease risk. Furthermore, socio-economic inequalities influence both exposure to environmental hazards and access to preventive services, contributing to spatial disparities in dengue incidence across urban areas (Lefebvre et al., 2022; Cofone et al., 2025; Moreno-López et al., 2025; Ali et al., 2025).

Although a considerable amount of literature has appeared, there are several important ones that have limitations. Investigations tend to concentrate on the climatic factors that influence the transmission of dengue, and environmental governance factors are comparatively under-researched. Studies on waste management often focus on the ecology of the mosquito, but do not consider the wider context of urban waste management systems. Furthermore, most studies are based on small-scale observations or short-term interventions, so the effects of structural waste management practices on dengue transmission over longer timeframes are not well understood (Harish et al., 2024). Existing evidence is also more likely to focus on the accumulation of waste as a standalone environmental issue rather than as part of a wider urban governance agenda with aspects of service provision, waste collection, community engagement and intersectoral working.

Another limitation concerns the insufficient integration of spatial epidemiology and waste management research. Although several studies have identified associations between environmental conditions and dengue outbreaks, limited empirical evidence explains how different waste management indicators interact with spatial clustering patterns of dengue cases in highly urbanized settings. Furthermore, previous research rarely incorporates both quantitative epidemiological evidence and qualitative stakeholder perspectives to explain the mechanisms linking

environmental management and disease transmission. As a result, important questions remain regarding how waste management systems contribute to urban dengue vulnerability and how improvements in environmental governance can reduce disease risk.

The state of the art in contemporary dengue research increasingly advocates integrated environmental approaches rather than conventional vector-control strategies alone. Emerging studies argue that sustainable urban health requires combining environmental management, sanitation improvement, community engagement, and institutional coordination. The One Health framework has become particularly influential in explaining how environmental conditions shape disease emergence and persistence. However, empirical applications of this framework within urban waste management and dengue prevention remain relatively limited, especially in rapidly urbanizing cities of developing countries where environmental pressures and infrastructure constraints coexist (Anugwom & Anugwom, 2023).

This study addresses these gaps by examining the relationship between waste management systems and dengue fever incidence in three major Indonesian cities: Jakarta, Surabaya, and Bandung. Unlike previous studies that focus primarily on climatic variables or isolated environmental conditions, this research adopts an integrated perspective that combines epidemiological analysis, spatial assessment, and stakeholder insights. The study investigates how waste collection frequency, waste segregation practices, and municipal service coverage influence dengue transmission patterns while simultaneously exploring the socio-institutional mechanisms underlying these relationships.

This work is novel for three reasons. First, it creates a multi-dimensional analytical framework that combines the waste management indicators with a spatial epidemiology and a perspective on urban governance in a single empirical research. Second, it investigates the temporal and spatial dynamics between waste management performance and the incidence of dengue in several metros. Third, it includes stakeholders' views from public health, waste management, urban planning, and community leaders to describe the governance structures that influence environmental health outcomes. This study is one of the first to link environmental management and public health research and offers evidence-based information to support a more robust dengue prevention program using integrated waste management strategies. The aim of this study is, therefore, to examine the correlation among urban waste management systems and incidence of dengue fever, to determine the environmental and governance factors that affect the transmission of dengue, and to develop policy recommendations for sustainable prevention of dengue in rapidly urbanizing contexts.

## METHODS

### Research Design

This study employed a sequential explanatory mixed-methods design to investigate the relationship between urban waste management systems and dengue fever incidence in major Indonesian cities. The mixed-methods approach was selected because the relationship between environmental management and vector-borne disease transmission involves both measurable epidemiological patterns and complex socio-institutional processes that cannot be fully explained through quantitative analysis alone. Following the framework proposed by Chaiyarit and et al. (2025), quantitative analysis was conducted in the first phase to identify statistical and spatial relationships between waste management indicators and dengue incidence, while qualitative inquiry was subsequently undertaken to explain the contextual mechanisms underlying the observed patterns. The integration of

both datasets enabled a comprehensive understanding of how waste management practices influence dengue transmission in urban environments.

### Study Area and Research Context

The study was conducted in three major Indonesian metropolitan areas: Jakarta, Surabaya, and Bandung. These cities were selected purposively because they represent highly urbanized settings characterized by dense populations, recurrent dengue outbreaks, and varying levels of waste management infrastructure. According to national public health reports, these urban centers consistently contribute a substantial proportion of reported dengue cases in Indonesia. The study period covered six consecutive years, from 2018 to 2023, allowing the investigation of both temporal and spatial variations in dengue incidence and waste management performance.

Administrative districts (kecamatan) within each city served as the primary units of analysis. The urban context provided an appropriate setting for examining how environmental management systems interact with population density, sanitation conditions, and public health outcomes.

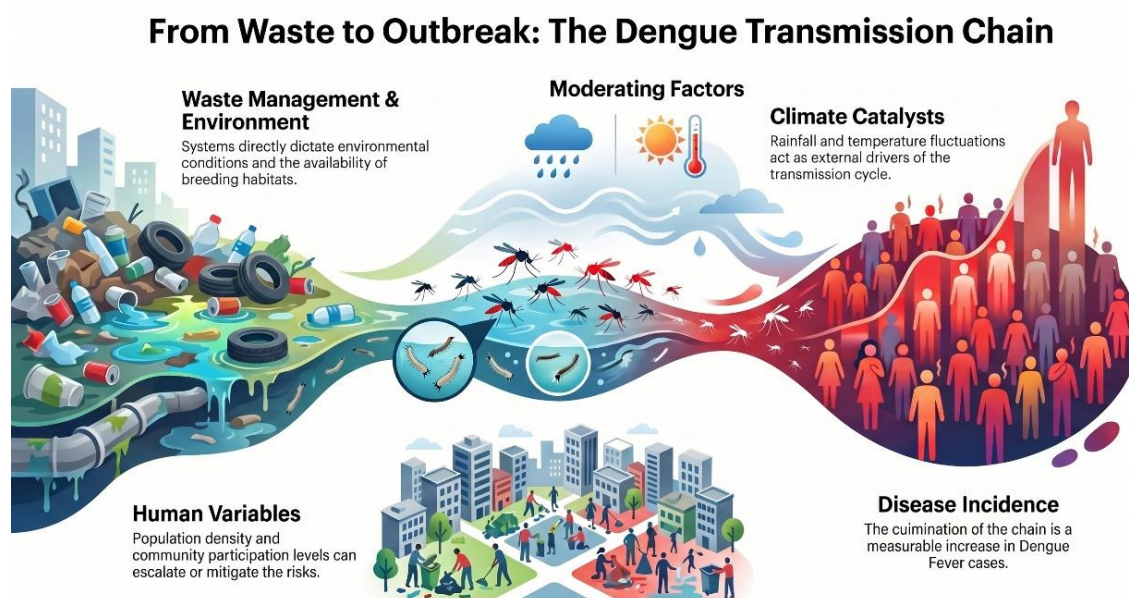


Figure 1. Conceptual Framework of the Relationship between Waste Management Systems and Dengue Fever Incidence.

Source: Developed by the Authors, 2026

Figure 1 illustrates the conceptual framework linking waste management practices, environmental conditions, mosquito breeding habitats, and dengue fever incidence.

### Data Collection Procedures

The study utilized both secondary and primary data sources. Quantitative data consisted of annual dengue fever incidence records obtained from municipal health surveillance systems in Jakarta, Surabaya, and Bandung. Only laboratory-confirmed dengue cases recorded between 2018 and 2023 were included in the analysis. Waste management data were collected from municipal environmental agencies and included waste collection frequency, household service coverage, waste segregation efficiency, and total waste volume managed annually. To control for environmental variability, meteorological data on rainfall and temperature were obtained from the Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG).

Qualitative data were collected through semi-structured interviews with twenty key informants selected using purposive sampling. The participants included public health officials, municipal waste management officers, urban planners, and community leaders directly involved in environmental health and waste management programs. Semi-structured interview protocols were designed to explore perceptions regarding the relationship between waste management practices and dengue prevention, implementation challenges, institutional coordination, and community participation. In addition, field observations were conducted in selected districts to verify environmental conditions, identify waste accumulation sites, and document potential mosquito breeding habitats.

### **Data Analysis**

Quantitative data analysis was conducted using descriptive and inferential statistical techniques. Descriptive statistics were employed to summarize dengue incidence rates and waste management indicators across the study locations. Pearson correlation analysis was used to examine the strength and direction of relationships between waste management variables and dengue incidence. Multiple linear regression analysis was subsequently performed to determine the predictive influence of waste management indicators while controlling for climatic factors such as rainfall and temperature (de Medeiros Engelmann et al., 2022).

Spatial analysis was undertaken using Geographic Information Systems (GIS) to identify geographical clustering patterns of dengue cases and waste accumulation sites. The Getis-Ord  $G_i^*$  statistic was applied to identify significant dengue hotspots, while Moran's  $I$  was used to evaluate spatial autocorrelation. Furthermore, cross-correlation analysis was employed to investigate temporal lag effects between changes in waste collection performance and subsequent dengue outbreaks.

Qualitative data were transcribed verbatim and analyzed using thematic analysis following the procedures proposed by Lee et al. (2021). The coding process involved data familiarization, initial code generation, theme development, theme refinement, and interpretation. Emerging themes were subsequently integrated with quantitative findings to explain the social, behavioral, and governance mechanisms underlying the statistical relationships.

### **Validity and Reliability**

Several strategies were employed to ensure methodological rigor. Quantitative data reliability was strengthened through the use of official government databases and consistency checks across multiple data sources. Multicollinearity diagnostics were performed prior to regression analysis to ensure model stability. Spatial validity was assessed using Moran's  $I$  and hotspot significance testing.

For qualitative data, credibility was enhanced through source triangulation involving multiple stakeholder groups and field observations. Member checking was conducted by sharing preliminary interpretations with selected participants to verify accuracy and consistency. Researcher triangulation was also employed during the coding and interpretation process to reduce subjective bias. The integration of quantitative, spatial, and qualitative evidence strengthened the overall validity of the study and provided a robust understanding of the relationship between waste management systems and dengue fever incidence in urban areas.

## **RESULTS AND DISCUSSION**

This section presents the empirical findings concerning the relationship between waste management systems and dengue fever incidence in urban areas. The analysis combines epidemiological records, waste management indicators, spatial mapping, temporal assessment, field observations, and stakeholder interviews collected from

Jakarta, Surabaya, and Bandung during the 2018–2023 period. The findings are organized into five interrelated sections. First, descriptive trends in dengue incidence and waste management performance are presented. Second, statistical relationships between waste management indicators and dengue incidence are examined through correlation and regression analyses. Third, spatial and temporal patterns of dengue transmission are analyzed. Fourth, environmental observations from the field are reported. Finally, qualitative findings from stakeholder interviews are presented to explain the institutional and behavioral mechanisms underlying the quantitative results.

### Descriptive Trends of Dengue Incidence and Waste Management Performance

A total of 12,673 laboratory-confirmed dengue cases were recorded across the three study locations during the observation period. Jakarta contributed the highest number of cases (4,890), followed by Bandung (4,503) and Surabaya (3,280). Although annual fluctuations were observed throughout the study period, dengue transmission remained persistent in all three cities.

To examine the environmental context of dengue transmission, waste management indicators were analyzed, including waste collection frequency, waste segregation efficiency, municipal service coverage, and annual rainfall conditions.

Table 1. Descriptive Summary of Dengue Incidence and Waste Management Indicators (2018–2023)

Variable	Jakarta	Surabaya	Bandung
Dengue incidence (per 100,000 population)	196.5	130.2	178.7
Waste collection frequency (times/week)	5	3	4
Waste segregation efficiency (%)	48	60	53
Municipal service coverage (%)	82	76	79
Average annual rainfall (mm)	2,360	1,980	2,120

Source: Municipal Health Departments, Environmental Agencies, and BMKG, 2018–2023

The descriptive results indicate that waste management performance varied considerably among the three cities. Jakarta maintained the highest collection frequency and service coverage but continued to report relatively high dengue incidence because of its dense population and extensive urban complexity. Surabaya exhibited the lowest dengue incidence despite lower service coverage, suggesting the possible influence of community-based environmental management initiatives. Bandung demonstrated intermediate values across most indicators. The descriptive findings suggest that waste management quality constitutes an important environmental factor influencing dengue transmission dynamics. Areas characterized by less frequent waste collection and lower service accessibility tended to experience higher disease burdens.

### Characteristics of Interview Participants

Twenty key informants participated in the qualitative phase of the study. Participants represented institutions directly involved in environmental management, public health governance, urban planning, and community mobilization.

Table 2. Characteristics of Interview Participants

Participant Category	Number
Public Health Officers	6
Waste Management Officials	5
Urban Planners	4
Community Leaders	5

Source: Interview Data, 2026

The diversity of participants provided multiple perspectives regarding environmental health challenges, waste management implementation, institutional coordination, and community participation in dengue prevention.

### Statistical Relationship Between Waste Management and Dengue Incidence

Pearson correlation analysis identified a statistically significant relationship between waste management performance and dengue incidence. Waste collection frequency demonstrated a moderate negative correlation with dengue incidence ( $r = -0.45$ ,  $p < 0.05$ ), indicating that more frequent waste removal was associated with lower disease occurrence. In contrast, waste segregation efficiency displayed a positive correlation ( $r = +0.37$ ,  $p < 0.05$ ). This finding suggests that waste separation programs may unintentionally increase mosquito breeding opportunities when segregated waste remains exposed before collection.

To further examine predictive effects, a multiple linear regression model was estimated.

Table 3. Multiple Linear Regression Predicting Dengue Incidence

Predictor	$\beta$ Coefficient	Std. Error	t-value	p-value
Waste collection frequency	-2.31	0.89	-2.59	0.017
Waste segregation efficiency	+0.15	0.06	2.55	0.019
Service coverage	-1.92	0.78	-2.45	0.023
Rainfall	+0.004	0.002	1.88	0.072
Temperature	+1.46	0.81	1.79	0.086

Model Statistics:  $R^2 = 0.41$ ;  $F(5,12) = 3.88$ ;  $p = 0.029$

Source: Statistical Analysis of Epidemiological and Environmental Data, 2026

The regression model explains approximately 41% of the variance in dengue incidence. Waste collection frequency emerged as the strongest protective factor, while service coverage also demonstrated a significant negative effect. Conversely, inefficient waste segregation increased the likelihood of dengue transmission. Climatic variables showed positive but statistically insignificant effects. These findings indicate that environmental management variables are stronger predictors of dengue incidence than climatic conditions within the study context.

### Spatial and Temporal Dynamics of Dengue Transmission

Spatial analysis identified significant clustering of dengue cases within districts characterized by waste accumulation and inadequate environmental infrastructure.

Table 4. Spatial Autocorrelation of Dengue Cases

City	Moran's I	z-score	p-value
Jakarta	0.224	4.53	<0.001
Surabaya	0.189	3.97	<0.001
Bandung	0.211	4.16	<0.001

Source: ArcGIS Spatial Analysis, 2026

The positive Moran's I values indicate significant spatial clustering rather than random disease distribution. Dengue hotspots were concentrated in Tanah Abang and Johar Baru (Jakarta), Bulak and Krembangan (Surabaya), and Cicadas and Kiaracandong (Bandung).

Jakarta, Surabaya, and Bandung (2018–2023)



Figure 2. Spatial Distribution of Dengue Hotspots and Waste Accumulation Sites

Source: GIS Mapping Analysis of Dengue Cases and Waste Management Infrastructure, 2026

The hotspot analysis revealed substantial overlap between dengue clusters and areas characterized by unmanaged waste, drainage obstruction, and informal dumping sites. These findings suggest that environmental conditions contribute directly to mosquito breeding and disease transmission.

Temporal analysis further revealed a delayed relationship between waste accumulation and dengue outbreaks.

Table 5. Time-Lag Relationship Between Waste Collection Decline and Dengue Incidence

Lag Interval	Correlation
1 Week	+0.18
2 Weeks	+0.33
3 Weeks	+0.49*
4 Weeks	+0.42*

Source: Cross-Correlation Analysis, 2026

The strongest correlation occurred after three weeks, suggesting that disruptions in waste collection create environmental conditions conducive to mosquito breeding and subsequent dengue transmission within approximately one month.

### Environmental Field Observation Findings

Field observations were conducted to verify environmental conditions reported by municipal agencies and interview participants.

Observations across all study sites revealed recurring environmental problems associated with dengue risk. These included unmanaged household waste, blocked

drainage channels, illegal dumping sites, and numerous water-holding plastic containers. Several densely populated neighborhoods exhibited inadequate waste storage facilities, resulting in prolonged waste accumulation.

In Jakarta, observations identified substantial waste accumulation in densely populated settlements where collection vehicles experienced limited access. In Surabaya, several peripheral districts demonstrated irregular collection schedules and temporary waste storage points exposed to rainfall. Bandung displayed relatively stronger community participation in neighborhood cleaning programs; however, container waste remained a common environmental concern. These observations support the quantitative findings by demonstrating how environmental conditions facilitate the creation of mosquito breeding habitats.

## **Stakeholder Perspectives on Waste Management and Dengue Prevention**

### ***Public Awareness of Waste-Related Dengue Risks***

Interview participants consistently reported that public understanding of the relationship between waste and dengue remains limited.

A public health officer explained:

*"Many residents still think dengue originates primarily from rivers or drainage systems. They rarely recognize that discarded plastic containers, cups, food packaging, and small household waste items can retain rainwater and become highly productive mosquito breeding sites. This misunderstanding continues to hinder prevention efforts."*

This statement indicates a substantial gap between public perception and environmental health realities.

A community leader further noted:

*"People often separate waste because they are told to do so, but they do not always understand the health consequences. Waste may be sorted correctly but then left outdoors for several days, creating conditions for mosquito breeding."*

This finding helps explain the positive relationship observed between segregation practices and dengue incidence.

Another public health official stated:

*"Awareness campaigns frequently focus on symptoms and treatment. Environmental prevention receives less attention, which limits behavioral change."*

Together, these findings demonstrate that environmental literacy remains a critical challenge.

### **Community Participation and Environmental Prevention**

Participants emphasized that community engagement strengthens municipal waste management systems.

A community leader reported:

*"When residents participate in monthly clean-up programs, environmental conditions improve significantly. People notice fewer mosquitoes, cleaner surroundings, and fewer health complaints among children."*

This statement highlights the protective role of collective environmental action.

A waste management officer explained:

*"Areas with active neighborhood waste programs consistently report fewer environmental complaints and lower dengue-related concerns."*

The observation supports quantitative evidence linking waste removal with reduced disease incidence.

A second community representative added:

*"Community participation creates continuous monitoring. Potential breeding sites are identified and removed before they become larger problems."*

These findings indicate that community involvement complements formal waste management services.

### **Institutional Coordination Challenges**

The final theme concerns governance limitations.

An urban planner explained:

*"Waste management, public health, and urban planning agencies often work independently. Information sharing usually occurs after outbreaks rather than before environmental risks emerge."*

This statement suggests reactive rather than preventive governance.

A public health officer added:

*"Most interventions focus on emergency response measures such as fogging. Less attention is given to addressing environmental conditions that allow mosquitoes to thrive."*

Another official stated:

*"Long-term dengue prevention requires integrated planning. Environmental management should become part of public health policy rather than a separate administrative responsibility."*

The qualitative findings reinforce the quantitative evidence by demonstrating that dengue prevention depends not only on technical waste management performance but also on community behavior, environmental awareness, and institutional coordination.

### **Urban Waste Management, Environmental Governance, and Dengue Transmission in Tropical Cities**

The findings of this study demonstrate that urban waste management constitutes a critical environmental determinant of dengue transmission in rapidly urbanizing settings. The observed negative association between waste collection frequency and dengue incidence reinforces growing evidence that environmental infrastructure plays a central role in shaping vector-borne disease dynamics. Previous studies have consistently reported that accumulated solid waste provides artificial water-holding containers that facilitate *Aedes aegypti* breeding and increase disease risk (Abdullah et al., 2024; Mahmud et al., 2023; Chaiyarit et al., 2025). The present findings extend this literature by demonstrating that waste management performance remains a significant predictor of dengue incidence even when climatic variables are considered. This result supports recent arguments that environmental governance factors should be incorporated into contemporary dengue risk models rather than relying primarily on rainfall and temperature indicators (Islam et al., 2025; Cofone et al., 2025).

The spatial analysis further revealed that dengue hotspots were concentrated in districts characterized by inadequate waste management infrastructure and limited municipal service accessibility. This finding is consistent with studies conducted in

Southeast Asia, which have shown that environmental inequalities often translate into unequal disease burdens across urban populations (Zainuddin et al., 2022; Samsudin et al., 2024). Similar patterns have been reported in Brazil, the Philippines, and other tropical regions where informal settlements experience greater exposure to environmental hazards and lower access to public services (Pereira et al., 2022; Ligsay et al., 2021). However, the current study contributes additional evidence by demonstrating how spatial clustering of dengue cases corresponds directly with waste accumulation sites identified through GIS-based analysis. This finding strengthens the argument that dengue transmission should be understood not only as a biological phenomenon but also as a manifestation of environmental and infrastructural vulnerability.

Another important finding concerns the role of community participation in reducing dengue risk. The qualitative evidence suggests that neighborhoods with active community-based waste management initiatives experience lower mosquito density and fewer disease complaints. This observation aligns with previous research emphasizing the importance of collective environmental action in vector control programs (Rodrigues et al., 2021; Pereira et al., 2022; Sarker et al., 2024). Nevertheless, the findings also indicate that community engagement alone is insufficient when municipal waste services remain inconsistent. Effective dengue prevention therefore requires a combination of formal institutional capacity and local social participation. This integrated perspective reflects the principles of the One Health framework, which emphasizes the interconnectedness of environmental, human, and governance systems in addressing complex public health challenges (Overgaard et al., 2021; Alqassim, 2024).

The study also revealed that fragmented coordination among health authorities, waste management agencies, and urban planning institutions continues to limit the effectiveness of dengue prevention strategies. Similar governance challenges have been identified in recent environmental health studies, where sectoral fragmentation often results in reactive interventions rather than preventive environmental management (Cuadros et al., 2024; Cheshmehzangi & Zou, 2025). The persistence of dengue hotspots despite routine mosquito control measures suggests that environmental drivers of transmission remain insufficiently addressed. Consequently, sustainable disease prevention requires stronger intersectoral collaboration, data sharing mechanisms, and integrated urban health planning.

From a theoretical perspective, this study contributes to the growing body of literature linking environmental governance and disease ecology. While previous research has primarily examined waste management as a supporting factor in vector control, the present study positions waste management systems as a central explanatory variable within urban dengue transmission. The integration of epidemiological analysis, spatial assessment, and stakeholder perspectives provides a multidimensional framework that expands current applications of the One Health approach. This framework represents the principal novelty of the study because it demonstrates how environmental infrastructure, governance capacity, and community behavior interact to shape disease outcomes in urban environments.

The findings suggest that municipal governments should prioritize regular waste collection, equitable service coverage, improved waste segregation systems, and community-based environmental education programs. Investments in waste infrastructure may generate public health benefits that extend beyond sanitation outcomes by directly reducing mosquito breeding opportunities and dengue transmission risk. Furthermore, the identification of spatial hotspots provides actionable information for targeting environmental interventions and resource allocation in high-risk districts.

Several implications emerge from these findings. First, dengue prevention policies should be integrated into broader urban environmental management strategies rather than relying solely on vector-control interventions. Second, waste management indicators should be incorporated into public health surveillance systems to improve outbreak prediction and preparedness. Third, local governments should strengthen collaboration among environmental, health, and planning sectors to support proactive risk management.

Despite these contributions, several limitations should be acknowledged. The study relied primarily on reported dengue cases, which may underestimate actual disease prevalence due to asymptomatic infections and underreporting. In addition, differences in municipal reporting systems may affect the consistency of waste management data across study locations. Although climatic variables were included in the statistical models, other environmental factors such as housing quality, land-use change, and vegetation density were not examined. Finally, the ecological nature of the analysis limits causal inference regarding the direct effects of waste management practices on dengue transmission.

Future research should investigate longitudinal impacts of integrated waste management interventions across diverse urban contexts and examine how environmental improvements influence disease outcomes over extended periods. Comparative studies involving additional metropolitan regions would improve the generalizability of findings. Moreover, future investigations should integrate remote sensing, machine learning, and real-time environmental monitoring technologies to enhance understanding of spatial and temporal dengue dynamics. Such approaches would strengthen evidence-based policymaking and contribute to more sustainable strategies for urban health and vector-borne disease prevention

## CONCLUSION

This study demonstrates that urban waste management systems play a critical role in shaping dengue fever transmission in densely populated cities. The findings indicate that regular waste collection, effective service coverage, and environmentally responsible waste practices contribute significantly to reducing mosquito breeding habitats and dengue incidence. Spatial analysis further reveals that dengue hotspots are concentrated in areas characterized by waste accumulation and infrastructural deficiencies, while qualitative evidence highlights the importance of community participation and intersectoral coordination in supporting sustainable disease prevention.

These findings contribute theoretically to the growing application of the One Health perspective by positioning waste management as a central determinant of urban disease ecology. Practically, the study emphasizes the need for integrated environmental governance, equitable waste services, and targeted interventions in high-risk areas. Nevertheless, limitations related to reported case data and ecological-level analysis should be acknowledged. Future research should employ longitudinal designs, incorporate additional environmental variables, and explore advanced spatial technologies to strengthen evidence-based dengue prevention strategies.

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