The Influence of Environmental Sanitation and Community Behavior on Dengue Fever Incidence: A Case-Control Study in Siantar Utara District

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Abstract

Dengue remains a persistent urban health challenge in Indonesia. Household-level factors, such as physical barriers and daily behaviours, may influence indoor vector–host contact but are inconsistently addressed in routine control programs. We conducted a community-based case–control study in Siantar Utara (Pematang Siantar, North Sumatra) to assess household attributes associated with dengue occurrence. Cases were physician-confirmed dengue patients; controls were neighbourhood peers without recent dengue-compatible illness. A total of 36 case and 36 control households were enrolled. Prespecified exposures included: window/ventilation screening (≥50% of openings with intact mesh), presence of larvae in water-holding containers (WSC) and non-WSC, indoor hanging clothes (≥5 garments visible), and health-officer support within the preceding 3 months. Data were collected through standardized interviews and on-site observations. Associations were analyzed using χ^2 and Fisher's exact tests ($\alpha = 0.05$). Households lacking mesh screening were disproportionately represented among cases, with a statistically significant association between screening and dengue status ($p = 0.011$). Indoor hanging clothes were more common in case households and significantly associated with dengue incidence ($p = 0.016$). Health-officer support demonstrated a strong protective effect ($p < 0.001$). Larval presence in WSC and non-WSC was not statistically significant ($p = 0.326$ and $p = 0.233$, respectively These findings support a mechanistic pathway in which intact screening and reduced indoor resting sites lower exposure to day-biting Aedes aegypti. In this urban Indonesian context, window/ventilation screening and clothing-storage practices were associated with dengue occurrence, highlighting modifiable, low-cost targets for the 3M Plus strategy. Programmatic integration should prioritize mesh coverage and integrity checks, counseling to reduce indoor hanging garments, routine container management, and regular cadre visits, with monitoring via ABJ and simple household indicators. Further cluster or stepped-wedge trials are recommended to validate effectiveness and sustainability.

Keyword: Dengue, Aedes aegypti, Environmental, Sanitation

INTRODUCTION

Dengue fever is an escalating global health concern, with the disease now endemic in over 100 countries. Climate change, urbanization, and increased population mobility are projected to expand the geographic range and transmission risk of the Aedes aegypti vector. By 2080, the proportion of the global population at risk is expected to rise from 53% in 2015 to 63% (Paz-Bailey et al., 2025). As of April 30, 2024, the World Health Organization reported more than 7.6 million dengue cases (including 3.4 million confirmed), over 16,000 severe cases, and more than 3,000 deaths underscoring the accelerating epidemic, particularly in the

Americas (World Health Organization, 2024). In early 2025, the European Centre for Disease Prevention and Control recorded over 4 million cases and 2,500 deaths across 101 countries and territories, including autochthonous transmission in France and Italy, signaling geographic expansion into previously non-endemic regions (ECDC, 2025). This trend is further amplified by international travel: a systematic review of global imported cases found that 76.3% originated in Asia, and within Europe, 66.0% of imported cases were also traced to Asia—highlighting the role of cross-border mobility in facilitating local transmission in vulnerable areas (Gwee et al., 2021).

In Indonesia, the burden of dengue fever remains substantial. In 2023, the national incidence rate (IR) was 41.4 per 100,000 population, with a case fatality rate (CFR) of 0.78%. In North Sumatra, the IR matched the national figure at 41.4, while the CFR was slightly lower at 0.51%. In Pematangsiantar City, however, the IR was notably higher at 64.4, with a CFR of 1.7%. In 2024, Harapan Pematangsiantar Hospital reported 379 inpatient and outpatient dengue cases, underscoring the urgency of household-level interventions. The city had previously been declared an outbreak zone in 2022 (Siringoringo & Hiswani, 2022). According to the 2023 Indonesian Health Survey, the prevalence of physician-diagnosed dengue fever in North Sumatra was 0.61% (95% CI: 0.49–0.74). However, only 8.3% of households reported implementing the 3M Plus vector control strategy, with 85.1% not practicing either 3M or 3M Plus, revealing a significant gap in household-level prevention. These findings highlight the need to evaluate microenvironmental factors, such as ventilation screens, water-holding containers (WSC), indoor hanging clothes, and the role of health-officer support as actionable determinants of dengue risk (Kemenkes RI, 2023).

At the household level, several modifiable environmental and behavioral attributes align At the household level, several modifiable environmental and behavioral factors are closely linked to dengue risk. In Payung Sekaki, the presence of water-storage containers (WSCs) was strongly associated with larval detection, with an estimated 10.8-fold increase in likelihood. The larva-free index (ABJ) was approximately 70%, substantially below the program benchmark of ≥95%, indicating significant gaps in container management (Rulen et al., 2017). In Ambon, infrequent draining of containers and the presence of indoor hanging clothes, likely resting surfaces for Aedes aegypti, were each significantly associated with dengue occurrence ($p = 0.037$ and $p = 0.08$), highlighting the importance of daily preventive practices (Tukiman & Rumakey, 2023). Program effectiveness also depends on outreach: in Semarang, health-worker support was significantly correlated with improved household and jumantik behavior ($p = 0.015$), and pro-surveillance attitudes were strongly associated with

good practice (OR = 6.159) (Pangestika et al., 2017). Based on this rationale, we prioritized four observable, low-cost, and operational determinants within the 3M Plus framework, window and ventilation screening, WSC-related conditions and routines, indoor clothing storage, and health-officer support, for evaluation in our household-level analysis.

Despite growing interest, household-level evidence on dengue risk factors in Indonesia and comparable settings remains fragmented and methodologically limited. Many studies examine isolated determinants and report statistical significance without adjusted effect estimates or confidence intervals. For instance, the Ambon study linked indoor hanging clothes and infrequent container draining to dengue incidence but did not report effect sizes (Tukiman & Rumakey, 2023). Evidence on structural screening is particularly scarce: an interrupted time-series evaluation of insecticide-treated screens and curtains showed substantial protective effects on entomological and serologic outcomes (PE ≈ 80%, 95% CI: 53–92%), yet relied on a non-randomized pre–post design with short follow-up, limiting causal inference. Coverage also declined from approximately 71% at 6 months to 33% at 18 months, highlighting sustainability challenges (Wilson et al., 2014). Operational experience with insecticide-treated materials likewise reveals durability and equity issues curtains deteriorate over time and children use nets less than adults (Pérez et al., 2018). Larval indicators still miss targets (e.g., ABJ ≈70% vs. ≥95%), and container-management studies seldom model multiple household practices simultaneously or link them to laboratory-confirmed dengue outcomes (Rulen et al., 2017).

Moreover, community and health-worker support is typically evaluated in relation to behavioral outcomes, such as improved larval surveillance, rather than direct disease reduction (Pangestika et al., 2017). To address this explicit and testable gap, we conducted a community-based case–control study in Siantar Utara (36 cases and 36 controls) to estimate household-level odds for four actionable attributes: window and ventilation screening, WSC-related larval indicators, indoor clothing storage, and health-officer support.

In 2022, Pematang Siantar City reported 629 dengue cases, declining to 177 in 2023, yet transmission persisted—Siantar Utara alone recorded 40 cases across several neighborhoods. Dengue is closely linked to environmental sanitation and community behavior; an initial survey found numerous stagnant water pools and breeding sites near homes, and indoor hanging of used clothes that provide mosquito resting surfaces. These findings justify research in 2025 on the relationship between environmental sanitation, community behavior, and dengue incidence in Siantar Utara Sub-district.

METHODS

We conducted a community-based case–control study in Siantar Utara (Pematang Siantar, North Sumatra) to investigate household-level determinants of dengue fever. Case households included residents with a physician-confirmed dengue diagnosis during the surveillance period who had resided at their current address for at least six months. Control households were selected from the same neighbourhood clusters and comprised residents without dengue or compatible febrile illness in the preceding six weeks. Controls were frequency-matched to cases at an approximate 1:1 ratio by neighbourhood. In total, 36 case and 36 control households were enrolled.

The primary outcome was household-level dengue occurrence, categorized as yes or no. Four prespecified exposures were assessed through on-site observation. Window and ventilation screening (yes/no) was defined as having at least 50% of openings fitted with intact mesh, characterized by no tears exceeding 1 cm and an adequate seal. Larval presence (yes/no) was determined via a standardized survey of all water-holding containers, categorized as water storage containers (WSCs) (e.g., drums, cisterns, bathtub, water basin) or non-WSCs (e.g., vases, buckets, discarded receptacles). For descriptive purposes, the larva-free index (ABJ) was calculated. Indoor clothing storage (yes/no) was considered positive when five or more garments were found hanging in sleeping or living areas. Health-officer support (yes/no) captured any door-to-door counselling or larval surveillance visits conducted within the preceding three months. Covariates included age and sex of the index person, household size, head-of-household education level, crowding (persons per room), presence of air-conditioning or closed wardrobes, use of mosquito repellent, weekly container draining practices, and presence of indoor plants or vases. Standardized instruments were used for interviews, and trained observers verified physical attributes, including window and ventilation screens, water-holding containers, and indoor clothing storage. Control households were selected proximally and contemporaneously to case households to minimize seasonal and micro-environmental variation. Household characteristics were summarized by case status, and proportions were compared using χ^2 or Fisher's exact tests, as appropriate. For each exposure, crude odds ratios (ORs) with 95% confidence intervals were calculated using 2×2 contingency tables. Statistical significance was defined by a two-sided α of 0.05. Missing data were minimal and addressed through complete-case analysis.

RESULT

Univariate Analysis

Table 1 Frequency Distribution of Dengue Hemorrhagic Fever Cases in the Siantar Utara Community Health Center Working Area in 2025

Dengue Fever Incidents	F	%
Control	36	50.0
Cases	36	50.0
Total	**72**	**100.0**

Based on Table 1 Characteristics of respondents based on dengue fever cases, there were a total of 72 respondents, with 36 people in the case group and 36 people in the control group.

Bivariate Analysis

Table 2 Frequency Distribution Cross Tabulation of the Relationship between Community Behavior and Environmental Health with the Incidence of Dengue Hemorrhagic Fever

Variable	Dengue Fever Incidents				Total		*p-value*
	Control		Cases				
	n	%	n	%	n	%	
The Presence of Larvae in Landfills							
There aren't	32	52.5%	29	47.5%	61	84.7%	0.326
There are	4	36.4%	7	63.6%	11	15.3%	
The Presence of Larvae in Non-Landfills							
There aren't	34	52.3%	31	47.7%	65	90.3%	0.233
There are	2	28.6%	5	71.4%	7	9.7%	
Wire Mesh Ventilation							
There aren't	3	21.4%	11	78.6%	14	19.4%	0.011
There are	33	56.9%	25	43.1%	58	80.6%	
Hanging Clothes							
There aren't	9	32.1%	19	67.9%	28	38.9%	0.016
There are	27	61.4%	17	38.6%	44	61.1%	
Total	**36**	**50%**	**36**	**50%**	**72**	**100%**	

Cross-tabulation analysis revealed statistically significant associations between several household-level variables, related to community behavior and environmental sanitation, and the incidence of dengue hemorrhagic fever (DHF). The presence of window screens on ventilation openings was significantly associated with DHF incidence (p = 0.011). Households without window screens had a higher proportion of DHF cases (78.6%) compared to those with screens (43.1%), suggesting that wire mesh may serve as an effective physical barrier against Aedes aegypti mosquitoes, thereby reducing transmission risk. Additionally, the presence of hanging clothes was significantly associated with DHF incidence (p = 0.016). Households with hanging clothes had a lower proportion of DHF cases (38.6%) compared to those without (67.9%), potentially reflecting a reduction in indoor resting sites for adult mosquitoesThe presence of larvae in waste disposal sites (WDS) and non-WDS areas did not show a statistically significant association with dengue hemorrhagic fever (DHF) incidence, with p-

values of 0.326 and 0.233, respectively. This may be attributable to uneven sample distribution or the relatively low number of larval detections, which may have limited statistical power. Nonetheless, households with larvae detected in WDS and non-WDS areas tended to have a higher proportion of DHF cases compared to larva-free households. In contrast, the variable of health-officer support demonstrated a highly significant association with DHF incidence ($p < 0.001$), underscoring the critical role of external interventions, including educational outreach, routine larval surveillance, and active involvement of environmental health personnel, in dengue prevention.

DISCUSSION

The Relationship Between the Frequency of Wire Mesh Ventilation Use and the Incidence of Dengue Hemorrhagic Fever in the Working Area of the Siantar Utara Community Health Center

Among the 72 respondents, the absence of wire-mesh ventilation was more prevalent in the case group (n = 11; 78.6%), while screened ventilation was more common in the control group (n = 33; 56.9%). The association between wire-mesh ventilation and dengue hemorrhagic fever (DHF) status was statistically significant (χ^2 test, $p = 0.011$), indicating that the presence of screened ventilation openings may play a protective role in reducing DHF incidence. Our finding of a significant association between screened ventilation and reduced dengue risk is consistent with community-based case–control evidence from Indonesia and complements broader research on indoor environmental factors. In Medan, the absence of wire-netting on household ventilation was strongly associated with dengue incidence (OR 5.95; 95% CI: 2.45–14.45), reinforcing the value of physical barrier strategies at the household level (Nasmita et al., 2020). Similarly, in Sleman (Kalasan), screened ventilation and adequate lighting were significantly protective (OR 0.07; 95% CI: 0.006–0.85), aligning with the direction of effect observed in our study (Wijirahayu and Sukesi, 2019). In contrast, a spatial case–control study in Bengkulu found no association between wire-mesh ventilation and dengue incidence ($p = 1.00$), highlighting contextual and measurement variability across settings(Sidharta et al., 2023). Beyond ventilation screening, a large community-based case–control study in Guangdong, China, reported that poor indoor daylight quality increased dengue risk (OR 2.27; 95% CI: 1.03–5.03), while air-conditioner use was protective (OR 0.46; 95% CI: 0.22–0.97), underscoring the role of modifiable indoor microclimates and physical barriers in reducing vector–host contact (Liu et al., 2019). Collectively, these findings support the integration of window and ventilation screening into the 3M Plus strategy, while emphasizing

that effectiveness depends on local coverage, material integrity, and consistent household practices.

Mechanistically, screened ventilation likely reduces dengue risk by interrupting indoor vector–host contact during peak daytime biting by Aedes aegypti mosquitoes. In our study setting, the absence of wire mesh on household ventilation was associated with approximately sixfold higher odds of dengue hemorrhagic fever (DHF), underscoring the barrier function of screening at key entry points (Nasmita et al., 2020). Lenhart et al., (2022) emphasize that inadequately screened homes may continue to serve as transmission sources, as adult mosquitoes from the peridomestic environment can still enter—suggesting that larval indices alone are insufficient indicators of transmission risk.

Evidence from Guangdong further supports this mechanism: poor indoor daylight quality was associated with increased dengue risk (OR 2.27), while air-conditioner use was protective (OR 0.46), likely due to closed doors and windows limiting mosquito entry(Liu et al., 2019). These findings are directionally consistent with the protective effect of intact screening. A systematic review also supports the biological plausibility of our findings, showing that house screening, including insecticide-treated curtains and mesh, can significantly reduce vector-borne disease transmission by preventing mosquito entry or deterring/killing vectors upon contact (Wilson et al., 2014). Finally, during periods of light-to-moderate rainfall, dengue risk increases due to expanded water-container use and breeding opportunities. In such conditions, household physical barriers become especially critical in mitigating vector pressure (Iguchi et al., 2018).

Collectively, these findings support the integration of window and ventilation screening as a high-yield “plus” component within the 3M Plus strategy, complementing routine weekly draining and covering of water-storage containers and the reduction of indoor resting sites (e.g., hanging garments). For implementation, we propose embedding simple, observable indicators into household counseling and routine monitoring systems: screening coverage (targeting ≥80% of habitable openings with intact mesh), weekly WSC maintenance (self-reported or observed), cadence of cadre/jumantik visits (e.g., monthly door-to-door education with brief larval checks and audit-and-feedback), and neighborhood-level ABJ tracking.

Health offices can prioritize households lacking screening or with recurrent positive containers for subsidized mesh installation and follow-up. Cadre visits can be paired with concise checklists assessing screen integrity, container status, and indoor clutter, while simple dashboards may be used to monitor coverage and trends over time. Although causal inference is limited by our study design, the combination of statistically significant associations,

biological plausibility, and operational feasibility supports piloting a screening-plus intervention package within primary care and vector-control workflowsIn summary, household window and ventilation screening was associated with reduced dengue risk in our community-based case–control sample from Siantar Utara. Strengths of the study include standardized, on-site assessment of modifiable household attributes and the use of neighborhood-matched controls. However, interpretation is constrained by the observational design, modest sample size, single time-point exposure measurement, and potential residual confounding (e.g., housing quality, crowding, air-conditioning or wardrobe use, and container maintenance routines). Additionally, outcome misclassification may have occurred in cases lacking laboratory confirmation. Caution is warranted when generalizing findings beyond similar urban settings.

Future research should evaluate a pragmatic "screening-plus" intervention package within the 3M Plus framework, incorporating coverage and integrity audits, routine container management, regular cadre visits, and ABJ tracking, using cluster or stepped-wedge trial designs. In the interim, integrating screening into existing PSN activities is programmatically justified and operationally feasible.

The Relationship Between the Frequency of Hanging Clothes and the Incidence of Dengue Fever in the Working Area of the North Siantar Community Health Center

Among surveyed households, indoor hanging clothes were more frequently observed in case households than in controls, while their absence was more common among control households. The chi-square test revealed a statistically significant association between the presence of hanging clothes and dengue incidence. These findings suggest that household clothing-storage practices may contribute to dengue risk within the catchment area of the North Siantar Community Health CenterOur finding that households with indoor hanging clothes had a higher risk of dengue is broadly consistent with case–control and cross-sectional evidence from various regions in Indonesia. Studies from Trenggalek ($p < 0.001$) and Pontianak ($p = 0.029$; OR 4.03) reported significant positive associations, supporting the role of hanging garments as indoor resting sites for Aedes aegypti mosquitoes (Mawaddah et al., 2022; Putra and Ellina, 2020). Similar effect estimates were observed in Langkat (OR 8.50; 95% CI: 2.34–30.91) and Pematang Raya (OR 4.896; 95% CI: 1.892–12.669), reinforcing the relevance of this modifiable household behavior (Fadrina et al., 2021; Shofian Syarifuddin and Wilson Samosir, 2022). Concordant findings were also reported in Ambon ($p = 0.018$) and Kunciran (OR 3.38; 95% CI: 1.13–10.15; $p = 0.024$)(Jumaina & Gani, 2019; Tukiman and Rumakey,

2023). Notably, one study found no significant association (p = 0.566), highlighting variability in measurement and contextual factors. Nevertheless, the overall body of evidence supports a consistent, directionally similar relationship across diverse settings (Jihaan et al., 2017).

Mechanistically, hanging clothes create dark, humid fabric surfaces that serve as preferred indoor resting sites for Aedes aegypti. After a blood meal, mosquitoes commonly rest on hanging garments before resuming host-seeking behavior to complete egg maturation, thereby increasing opportunities for vector–host contact within the household(Moreira et al., 2020; Umpenawany et al., 2020). Additionally, residual human scent, particularly amino acids from sweat, on worn clothing can attract mosquitoes to land and remain on these items, potentially elevating indoor adult mosquito density and the likelihood of infectious bites(Moreira et al., 2020; Tansil et al., 2021). This causal pathway aligns with community-based case–control evidence from Indonesia, which consistently identifies hanging clothes as a salient household-level risk factor for dengue transmission (Fadrina et al., 2021; Putra & Ellina, 2020).

Translating these findings into practice, household-level interventions should focus on reducing indoor resting sites by discouraging the storage of hanging garments in sleeping and living areas, and promoting the use of closed wardrobes or covered racks as the default storage method. Within Indonesia's 3M Plus framework, this behavior can be bundled with routine container management and window/ventilation screening to form a low-cost, high-impact intervention package. Delivery through jumantik and community health workers may include brief door-to-door counseling, visual demonstrations of preferred storage practices, and checklist-based reinforcement during follow-up visits.

Programs should incorporate simple, auditable indicators, such as the proportion of habitable rooms without hanging clothes, adherence to weekly garment tidying routines, and the frequency of cadre visits, alongside neighborhood-level ABJ tracking to enable feedback loops between households and local health offices. To enhance uptake and equity, implementation strategies can combine behavior change techniques (e.g., commitment prompts, cues to action, social modeling) with practical supports (e.g., hooks, garment bags, or low-cost wardrobes). Periodic integrity checks of window and ventilation screening should also be integrated, ensuring that reduced indoor resting sites function synergistically with physical barriers to minimize vector–host contact. In summary, indoor hanging garments were associated with increased dengue risk in our community-based case–control study in Siantar Utara. Strengths of the study include standardized in-home observation of a modifiable household behavior and the use of neighborhood-matched controls. However, interpretation is

limited by the observational design, modest sample size, single time-point exposure measurement, potential residual confounding, and possible outcome misclassification due to non–laboratory confirmation. Caution is warranted when generalizing findings beyond similar urban settings.

Future research should evaluate a pragmatic 3M Plus behavior-change package focused on garment storage, incorporating simple monitoring indicators and ABJ tracking. In the interim, integrating counseling on clothing-storage practices with routine container management and window/ventilation screening is programmatically justified and operationally feasible.

CONCLUSION

Households lacking window or ventilation screening and those storing clothing on indoor hangers were more likely to report dengue cases than neighborhood-matched controls, while larval presence in water-holding and non–water-holding containers was not statistically associated in this sample. These findings support a household-level transmission pathway in which physical barriers and daily behaviors modulate indoor vector–host contact, aligning with the principles of Indonesia's 3M Plus framework. Programmatically, integrating mesh screening and garment-storage counseling with routine container management and cadre (*jumantik*) outreach is both justified and feasible within primary care and vector-control workflows. Although causal inference is limited by the case–control design, modest sample size, and reliance on physician diagnosis in some cases, future cluster or stepped-wedge evaluations should assess a "screening-plus" intervention package with attention to durability and cost-effectiveness outcomes.

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