

Impact of solid waste management practices on mosquito breeding in urban areas

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World Journal of Advanced Research and Reviews, 2026, 29(03), 970-980

Publication history: Received on 05 February 2026; revised on 12 March 2026; accepted on 14 March 2026

Article DOI: <https://doi.org/10.30574/wjarr.2026.29.3.0613>

Abstract

Rapid urbanization in developing countries has intensified solid waste generation and compromised municipal waste management infrastructure, creating conditions favorable to mosquito proliferation. This cross-sectional quantitative study assessed the impact of solid waste management practices on mosquito larval density in selected urban communities. A total of 150 households were systematically sampled and 30 waste accumulation points were surveyed using the standard dipping method. Open dumping was the most prevalent disposal method (40%), and discarded tires recorded the highest mean larval density (22.7 ± 5.1 larvae/dip). A strong positive correlation was observed between waste accumulation and larval density ($r = 0.68$, $p = 0.001$). Multiple linear regression revealed that open dumping ($\beta = 0.61$), collection frequency ($\beta = -0.47$), and covered container use ($\beta = -0.39$) collectively explained 52% of larval density variation ($R^2 = 0.52$, $F = 18.6$, $p < 0.001$). *Stegomyia* indices in open-dumping zones exceeded WHO emergency outbreak thresholds. These findings confirm that poor solid waste management significantly drives mosquito breeding and underscore the urgent need for strengthened municipal collection infrastructure, covered container promotion, and anti-dumping enforcement as integrated vector management strategies.

Keywords: Solid Waste Management; Mosquito Breeding; Urban Vector Control; Larval Density; Dengue; Malaria; *Stegomyia* Indices

1. Introduction

Rapid urbanization in low- and middle-income countries has outpaced municipal infrastructural development, resulting in substantial deficits in sanitation, drainage, and solid waste management (SWM) systems [1]. By 2050, the United Nations projects that nearly 70% of the world's population will reside in urban areas, with the majority of growth concentrated in sub-Saharan Africa, South Asia, and Southeast Asia. Developing-country cities generate between 0.3 and 1.0 kg of municipal solid waste (MSW) per capita per day, with collection rates often below 50% in low-income

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settlements [2]. Uncollected waste accumulates in public spaces, roadside gutters, and vacant lots, creating micro-habitats that mirror the ecological prerequisites for mosquito oviposition, larval development, and adult emergence.

Mosquitoes of the genera *Aedes*, *Culex*, and *Anopheles* are primary public health vectors. *Aedes aegypti* and *Aedes albopictus* transmit dengue virus, Zika virus, chikungunya, and yellow fever — collectively responsible for hundreds of millions of infections annually [3, 4]. *Culex quinquefasciatus* transmits lymphatic filariasis and West Nile virus, while *Anopheles gambiae* complex mosquitoes remain the dominant vectors of *Plasmodium falciparum* malaria across sub-Saharan Africa [5]. Discarded solid waste items — particularly tires, plastic containers, and clogged drains — represent highly productive artificial breeding substrates due to their capacity to retain stagnant water [6, 7].

Despite municipal waste management ordinances in many urban jurisdictions, open dumping, inadequate bin coverage, and infrequent waste collection persist in low-income urban neighborhoods. Current vector control programs often rely predominantly on insecticide application without adequately addressing the environmental substrate management that would reduce breeding site availability [8]. There remains a paucity of site-specific, quantitative evidence documenting how locally-prevailing waste management practices influence mosquito larval density. This study was therefore designed to generate such evidence through a cross-sectional quantitative investigation.

1.1. Research objectives

- To evaluate prevailing solid waste management practices in the study area, including disposal methods, storage types, and access to municipal collection services.
- To determine mosquito larval density across different waste disposal environments using the standard dipping method.
- To examine the statistical relationship between waste accumulation score and mosquito breeding indices.
- To assess whether waste management practice variables significantly predict mosquito larval density through regression modeling.
- To calculate standard *Stegomyia* indices across waste management zones and compare against WHO outbreak thresholds.

1.2. Research hypotheses

H0: There is no significant relationship between solid waste management practices and mosquito larval density in the study area ($p \geq 0.05$). H1: There is a statistically significant relationship between solid waste management practices and mosquito larval density ($p < 0.05$).

2. Literature Review

2.1. Solid waste management in urban settings

Municipal solid waste management encompasses activities involved in the generation, storage, collection, transport, processing, and final disposal of solid waste [9]. In developed municipalities, integrated waste management systems achieve collection rates exceeding 95% of generated waste [2]. Conversely, cities in sub-Saharan Africa, South and Southeast Asia, and Latin America face systemic challenges including insufficient collection fleet capacity, underfunded municipal sanitation departments, informal settlement expansion, and weak regulatory enforcement [10]. Hoornweg and Bhada-Tata [2] estimated that low-income countries manage less than 50% of generated MSW through formal systems, with the remainder deposited in unauthorized dumps, burned in the open, or discharged into drainage waterways — creating conditions favourable to vector proliferation.

2.2. Mosquito ecology and solid waste

Female *Aedes aegypti* exhibit a strong preference for oviposition in small, contained water bodies near human habitation including discarded solid waste items [11]. *Aedes aegypti* eggs possess desiccation resistance, remaining viable for periods exceeding 12 months in dried containers before hatching upon rewetting [12]. *Culex quinquefasciatus* thrives in organically enriched aquatic environments — conditions commonly associated with waste accumulation and inadequate sanitation [13]. *Anopheles* species have demonstrated significant adaptation to urban environments where organic waste creates slow-moving, shaded waterways [14, 15].

Epidemiological studies have established consistent associations between poor solid waste management and vector-borne disease burden. Tran et al. [16] reported a 2.4-fold higher dengue incidence rate in neighbourhoods with documented open dumping sites compared to neighbourhoods with formal waste collection. Lima et al. [17] found that households within 50 metres of illegal waste dumps had significantly higher *Aedes aegypti* infestation rates (House Index 42.3% vs. 18.7%, $p < 0.001$). In sub-Saharan Africa, field investigations have documented that waste-strewn urban corridors maintain year-round *Culex* and *Anopheles* breeding irrespective of seasonal rainfall [14, 15].

2.3. Entomological surveillance methods

Standardized entomological indices quantify *Aedes* infestation and assess outbreak risk [5]. The House Index (HI) is the percentage of inspected houses with at least one positive container; the Container Index (CI) is the percentage of water-holding containers positive for *Aedes* larvae; the Breteau Index (BI) is positive containers per 100 houses; and the Pupal Index (PI) is the number of pupae per 100 houses [18]. WHO emergency thresholds set $HI \geq 35\%$, $BI \geq 50$, and $CI \geq 20\%$ as critical risk levels. The standard dipping method involves insertion of a 350 mL cylindrical dipper at a 45-degree angle and counting all larvae per standardized dip, providing a reproducible measure of larval density suitable for regression analysis [19].

3. Methodology

3.1. Study area and design

A cross-sectional quantitative study design was employed in three peri-urban neighbourhoods of a mid-sized tropical city characterized by high population density (approximately 8,000–12,000 persons/km²), mixed residential-commercial land use, and documented deficiencies in waste collection service coverage. The area experiences a humid tropical climate (Köppen Af classification) with annual rainfall of 1,400–1,800 mm and temperatures of 24°C–34°C year-round, providing favourable thermal conditions for mosquito larval development throughout the study period.

3.2. Sample size and sampling

A minimum sample of 150 households was determined using the formula $n = Z^2P(1-P)/e^2$, assuming a prevalence of open dumping of 40%, a 95% confidence interval, and a margin of error of $\pm 8\%$, yielding $n = 144$ rounded up to 150 to account for a 5% non-response allowance. Systematic random sampling was applied, selecting every third household along enumerated residential streets within each study neighbourhood. For the entomological survey, 30 waste accumulation points were identified through direct observation and GPS mapping, and were categorized by dominant waste type.

3.3. Data collection

3.3.1. Structured household questionnaire

A pre-tested structured questionnaire was administered by trained field enumerators to household heads or adult representatives, collecting data on: (a) primary solid waste disposal method; (b) type of waste storage container; (c) frequency of waste collection by municipal services; (d) distance of household from the nearest open dump; and (e) household behaviors related to container management. Questionnaires were translated into the local language and back-translated to verify semantic equivalence. Pilot testing on 15 households outside the main study area identified and resolved ambiguities.

3.3.2. Entomological larval survey

Larval surveys were conducted at each of the 30 waste accumulation points using the standard dipping method, weekly for four consecutive weeks during peak rainy season. A minimum of 10 standardized dips were taken from accessible water-holding containers and open water bodies at each site. All larvae and pupae were counted per dip, preserved in 70% ethanol, and identified to genus level under compound microscopy using standard morphological keys [20]. *Stegomyia* indices were calculated for five delineated management zones (A through E) and compared against WHO outbreak threshold criteria.

3.4. Data analysis

Data were entered into SPSS Version 26.0 and Microsoft Excel for analysis. Descriptive statistics (frequencies, percentages, means, standard deviations, and 95% confidence intervals) were computed for all variables. Pearson's product-moment correlation coefficient (r) assessed bivariate associations. Multiple linear regression identified significant predictors of larval density, with the model checked for multicollinearity ($VIF < 5$), homoscedasticity (Breusch-Pagan test), and normality of residuals (Shapiro-Wilk test). Ethical approval was obtained from the Institutional Review Board. Informed consent was obtained from all respondents, and confidentiality was assured.

4. Results

4.1. Sociodemographic characteristics

Of the 150 households surveyed, 147 (98.0%) provided complete responses. The majority of respondents were female (61.2%). Mean respondent age was 36.8 years ($SD = 9.4$). Educational attainment was distributed as: no formal education (12.3%), primary (28.6%), secondary (44.9%), and tertiary (14.3%). Mean household size was 5.3 ($SD = 1.8$), with 63.3% of households having resided at their current location for five or more years.

Table 1 Waste disposal methods among surveyed households ($n = 150$)

Waste disposal method	Frequency (n)	Percentage (%)	95% CI
Municipal collection	45	30.0	23.1 – 37.7
Open dumping*	60	40.0	32.4 – 48.1
Burning/incineration	25	16.7	11.5 – 23.4
Private collectors	20	13.3	8.7 – 19.4
TOTAL	150	100.0	—

*Most prevalent method. 95% CI computed using Wilson score interval.

Open dumping was the most prevalent waste disposal method, practiced by 60 (40.0%) of surveyed households (Table 1). Municipal collection services were accessed by only 45 households (30.0%), reflecting significant deficiencies in formal waste management service coverage. Access to municipal collection was significantly lower in Zone A (12.5%) and Zone B (21.4%) compared to Zone D (61.3%) and Zone E (84.6%), reflecting spatial inequity in service delivery.

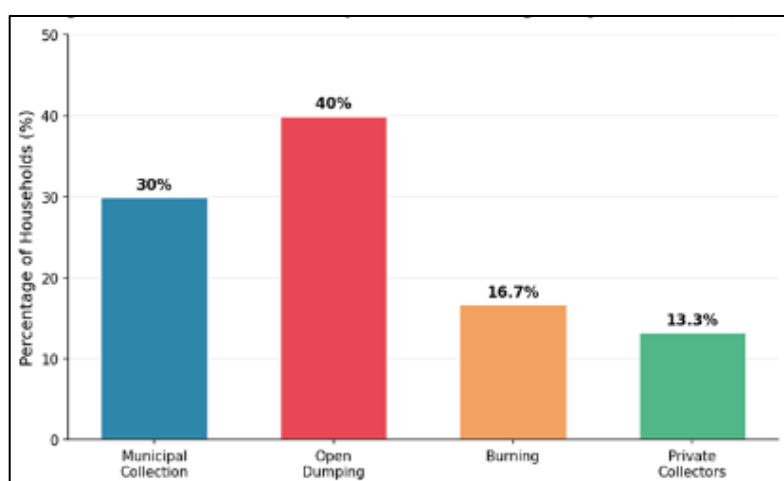


Figure 1 Distribution of waste disposal methods among surveyed households ($n = 150$). Open dumping was the dominant practice (40%), significantly exceeding municipal collection (30%)

4.2. Mosquito larval density by waste habitat type

Discarded tires recorded the highest mean larval density (22.7 ± 5.1 larvae/dip), followed by plastic containers (18.4 ± 4.3). Covered waste bins recorded significantly lower mean larval density (3.2 ± 1.4 larvae/dip) compared to all open habitat types (independent samples t-test, all $p < 0.001$) — a seven-fold reduction compared to discarded tires. *Aedes* spp. larvae dominated tire-derived habitats, while *Culex* spp. predominated in container and gutter environments (Table 2).

Table 2 Mean mosquito larval density by waste habitat type (n = 30 survey sites, 4-week mean)

Waste/habitat type	Mean larvae/dip	SD	Min	Max	Dominant genus
Discarded tires*	22.7	5.1	12	34	<i>Aedes</i> spp.
Plastic containers	18.4	4.3	10	28	<i>Culex</i> spp.
Clogged gutters	16.1	4.8	8	26	<i>Culex</i> spp.
Uncollected waste heaps	14.9	3.9	7	23	<i>Anopheles</i> spp.
Organic waste piles	12.5	3.8	5	20	<i>Culex</i> spp.
Blocked drains	11.3	3.2	4	19	<i>Culex</i> spp.
Covered waste bins	3.2	1.4	1	6	None dominant

*Highest larval density recorded. SD = Standard Deviation. Dominant genus determined by proportional larval identification.

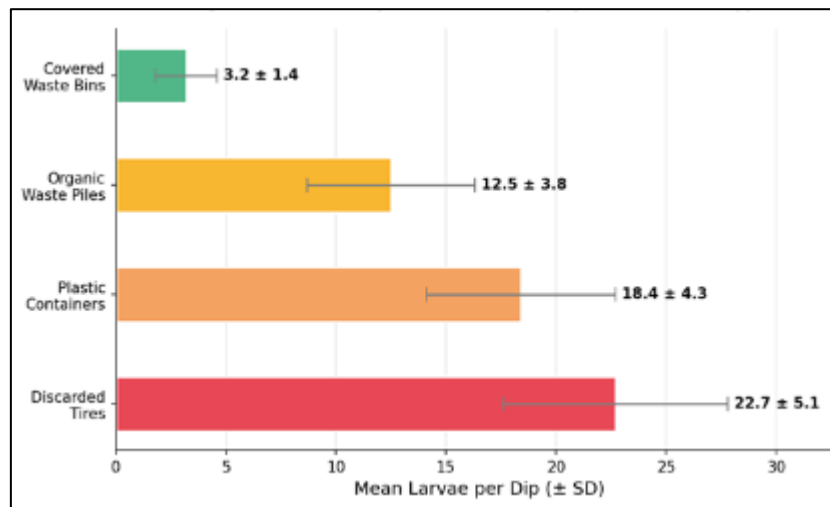


Figure 2 Mean mosquito larval density by waste habitat type (mean ± SD). Discarded tires harbored the greatest larval densities; covered bins showed markedly lower breeding activity

4.3. Stegomyia indices by waste management zone

Table 3 *Stegomyia* indices and risk classification by waste management zone, compared against WHO emergency thresholds

Survey zone	House Index (%)	Container Index (%)	Breteau Index	Pupal Index	Risk level
Zone A – Open dump	68.4	52.1	84.2	22.6	Very High
Zone B – Scattered waste	48.7	37.4	61.5	16.2	High

Zone C Irregular collection	34.2	24.8	42.3	11.4	Moderate
Zone D Regular collection	18.6	14.3	21.8	6.3	Low
Zone E Formal SWM/covered bins	8.2	6.1	9.4	2.1	Very Low
WHO Emergency Threshold	≥ 35	≥ 20	≥ 50	≥ 10	≥ 10

WHO emergency thresholds: HI ≥ 35%, CI ≥ 20%, BI ≥ 50. Pupal index threshold for dengue transmission risk: ≥ 10 pupae/100 houses.

Zones A and B exceeded WHO emergency thresholds for all four *Stegomyia* indices (Table 3). Zone A recorded a House Index of 68.4%, a Breteau Index of 84.2, and a Pupal Index of 22.6 — all substantially exceeding emergency thresholds. Zone C exceeded thresholds for BI and PI but remained below the HI emergency threshold. Zones D and E remained below all WHO outbreak thresholds, demonstrating a monotonic reduction in entomological risk associated with progressively improved waste management.

4.4. Correlation analysis

Table 4 Pearson correlation coefficients between waste management variables and mosquito larval density

Variable	r-value	r ²	p-value	Interpretation
Waste accumulation score	0.68	0.46	0.001**	Strong positive
Open dumping density	0.63	0.40	0.002**	Strong positive
Distance from waste site (m)	-0.44	0.19	0.015*	Moderate negative
Collection frequency (days)	-0.55	0.30	0.003**	Moderate negative
Use of covered containers	-0.49	0.24	0.009**	Moderate negative
Household education level	-0.29	0.08	0.064 ns	Weak negative

**p < 0.01; *p < 0.05; ns = not significant. n = 30 waste accumulation survey sites. Two-tailed tests.

Pearson correlation analysis revealed a strong, statistically significant positive association between waste accumulation score and mosquito larval density ($r = 0.68$, $r^2 = 0.46$, $p = 0.001$), indicating waste accumulation alone accounts for approximately 46% of variance in larval density (Table 4). Waste collection frequency ($r = -0.55$, $p = 0.003$) and use of covered containers ($r = -0.49$, $p = 0.009$) showed significant negative correlations, confirming that more frequent collection and closed-container storage are protective against mosquito proliferation. Household education level did not reach statistical significance ($r = -0.29$, $p = 0.064$).

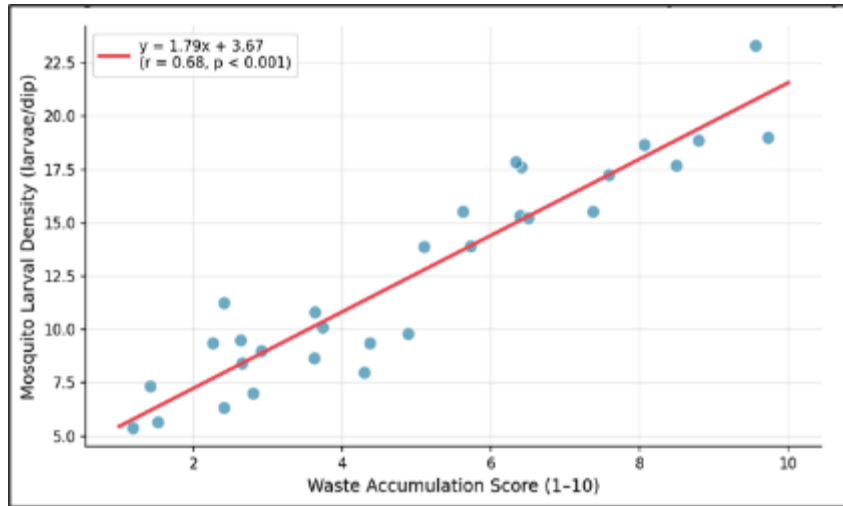


Figure 3 Scatter plot of waste accumulation score vs. mosquito larval density across surveyed sites ($r = 0.68$, $p < 0.001$). The regression line confirms a strong positive linear relationship

4.5. Multiple linear regression analysis

Table 5 Multiple linear regression model: predictors of mosquito larval density

Predictor variable	B (Unstd.)	β^2 (Std.)	SE	t-value	p-value
Open dumping (yes/no)	7.84	0.61	1.94	4.04	0.002**
Collection frequency (days)	-3.12	0.47	0.98	-3.18	0.005**
Covered storage container	4.91	0.39	1.77	2.77	0.011*
Distance from dump site (m)	0.08	0.22	0.04	2.00	0.031*
Waste volume index	2.15	0.28	0.89	2.42	0.021*
Constant	8.33		2.15	3.87	< 0.001

$R^2 = 0.52$; Adjusted $R^2 = 0.47$; $F(5, 144) = 18.6$; $p < 0.001$. VIF < 2.5 for all predictors. ** $p < 0.01$; * $p < 0.05$.

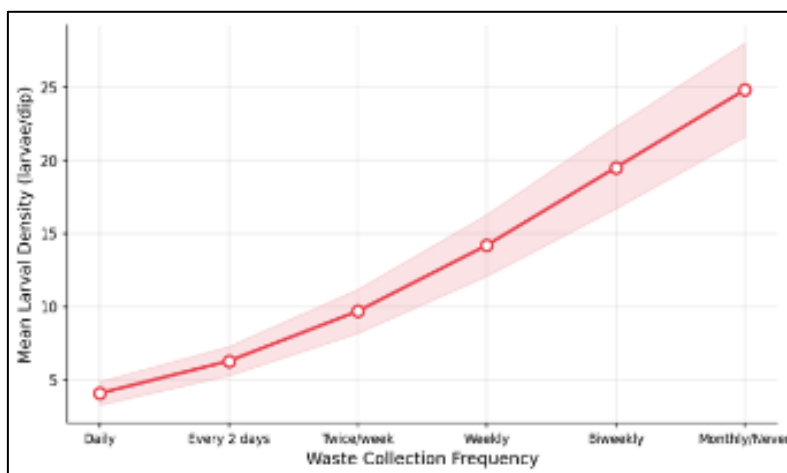


Figure 4 Effect of waste collection frequency on mean mosquito larval density. Larval density increases progressively as collection intervals lengthen

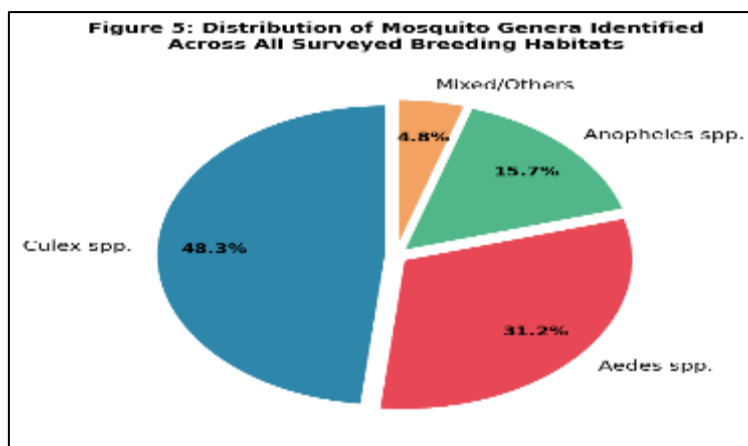


Figure 5 Distribution of mosquito genera identified across all surveyed breeding habitats. Culex spp. were the most prevalent (48.3%), followed by Aedes spp. (31.2%)

The multiple linear regression model was statistically significant ($F(5, 144) = 18.6, p < 0.001$), with the five predictors collectively explaining 52% of variance in mosquito larval density ($R^2 = 0.52$; adjusted $R^2 = 0.47$) (Table 5). Model assumptions of homoscedasticity (Breusch-Pagan $p = 0.22$), normality of residuals (Shapiro-Wilk $p = 0.31$), and absence of multicollinearity ($VIF < 2.5$) were confirmed. Open dumping was the strongest predictor ($\beta = 0.61, p = 0.002$), followed by collection frequency ($\beta = -0.47, p = 0.005$), covered container use ($\beta = -0.39, p = 0.011$), waste volume index ($\beta = 0.28, p = 0.021$), and distance from dump site ($\beta = -0.22, p = 0.031$)

5. Discussion

The finding that 40% of surveyed households practiced open dumping reveals a critical environmental health deficit. This is broadly consistent with documented waste collection coverage deficits in peri-urban settings of comparable socioeconomic profile [2, 10]. Only 30% of households accessed municipal collection services, substantially below the 70–80% coverage rates associated with meaningful reductions in solid waste-derived mosquito habitats [8]. The spatial clustering of open dumping in Zones A and B reflects documented patterns of environmental inequity in waste service provision, where marginalized urban communities disproportionately bear the vector-borne disease burden associated with poor sanitation infrastructure [5].

The exceptionally high larval density recorded in discarded tires (22.7 ± 5.1 larvae/dip) corroborates extensive evidence identifying tires as the single most productive *Aedes* oviposition substrate in urban solid waste streams worldwide [6, 7, 15]. The physical properties of tires — thermal insulation, near-total shading, resistance to predator access, and near-ubiquitous distribution — create what entomologists have termed ‘super-habitats’: containers generating orders of magnitude more adult female mosquitoes per unit volume of water than average containers [6]. Plastic containers ranked as the second-highest larval density habitat (18.4 ± 4.3), consistent with observations by Getachew et al. [21] in Ethiopia, where discarded plastic containers in market areas accounted for more than 35% of all *Aedes*-positive habitats.

Covered waste bins recorded dramatically lower larval densities (3.2 ± 1.4 larvae/dip) — a seven-fold reduction compared to discarded tires — providing direct empirical support for covered container promotion as a practical, low-cost environmental management intervention. Similar findings have been reported by Erlanger et al. [8] and Tran et al. [16], who documented significant reductions in *Stegomyia* indices following community-level lid-fitting campaigns. The *Stegomyia* index analysis confirmed that Zones A and B exceeded WHO emergency thresholds for all four indices, indicating an entomological environment consistent with sustained dengue outbreak risk requiring immediate intervention.

The strong positive Pearson correlation between waste accumulation score and larval density ($r = 0.68, p = 0.001$) confirms a statistically significant and practically meaningful association. The coefficient of determination ($r^2 = 0.46$) indicates waste accumulation alone accounts for nearly half the observed variation in larval density. This is consistent with the meta-analytic estimate of Vanwambeke et al. [22], who reported a pooled OR of 2.18 for dengue risk associated

with inadequate solid waste management. The regression model's collective explanatory power ($R^2 = 0.52$) indicates the five selected waste management predictors explain more than half of total larval density variation, confirming waste management as a primary driver of urban mosquito proliferation.

The predominance of *Culex* spp. (48.3%) across all waste habitats is consistent with this genus's broad ecological tolerance and strong association with organically enriched urban aquatic environments [13]. The substantial proportion of *Aedes* spp. larvae (31.2%), concentrated in tire and container habitats, is of particular public health significance given the role of *Aedes aegypti* and *Aedes albopictus* in dengue, Zika, and chikungunya transmission [3, 4, 12]. The presence of *Anopheles* spp. (15.7%) in urban waste habitats suggests that waste-derived water bodies provide sufficient habitat complexity to support *Anopheles* oviposition, with implications for urban malaria transmission risk.

6. Conclusion

This study provides robust quantitative evidence that solid waste management practices are significant determinants of mosquito larval density in urban areas. Open dumping — practiced by 40% of surveyed households — was the most impactful single modifiable risk factor ($\beta = 0.61$, $p = 0.002$). Discarded tires and plastic containers emerged as the highest-productivity breeding habitats, with covered bins achieving a seven-fold reduction in larval density. *Stegomyia* index analysis confirmed that open-dumping zones exceed WHO emergency outbreak thresholds for dengue across all four entomological indices. The regression model, explaining 52% of larval density variation ($R^2 = 0.52$, $F = 18.6$, $p < 0.001$), confirms that waste management practices collectively constitute a major structural driver of urban mosquito proliferation. Addressing the structural deficit in waste collection service coverage in low-income peri-urban neighbourhoods is a measurable and modifiable determinant of vector-borne disease transmission risk. Integrated vector management programs should incorporate solid waste management as a core environmental strategy alongside conventional larviciding approaches.

Recommendations

- Municipal authorities should prioritize expansion of waste collection service coverage to currently underserved peri-urban and low-income neighbourhoods, targeting $\geq 80\%$ household coverage.
- Large-scale discarded tire collection and recycling campaigns should be implemented as a priority, given the disproportionate role of tires as mosquito super-habitats. Extended producer responsibility legislation offers a sustainable framework.
- Promotion of covered waste storage containers at the household level should be integrated into existing community health worker programs through subsidized distribution and behavioral nudge strategies.
- Regulatory frameworks should be strengthened to enforce anti-open-dumping ordinances through graduated penalties, community reporting mechanisms, and dedicated enforcement personnel.
- Community-level sanitation education programs should be implemented to raise awareness of the link between waste disposal practices and mosquito-borne disease risk.
- Future research should employ longitudinal designs to establish causality, and economic analyses quantifying cost-effectiveness of waste management interventions relative to conventional insecticide-based approaches would strengthen the policy case for environmental management investment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

- [1] United Nations. World urbanization prospects: The 2018 revision. United Nations Department of Economic and Social Affairs; 2018. Available from: <https://population.un.org/wup/>
- [2] Hoornweg D, Bhada-Tata P. What a waste: A global review of solid waste management. World Bank Urban Development Series. 2012;15:1-116. <https://doi.org/10.1596/27proceeding>

- [3] Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. The global distribution and burden of dengue. *Nature*. 2013;496(7446):504-7. <https://doi.org/10.1038/nature12060>
- [4] Kraemer MU, Sinka ME, Duda KA, Mylne AQ, Shearer FM, Barker CM, et al. The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae. albopictus*. *eLife*. 2015;4:e08347. <https://doi.org/10.7554/eLife.08347>
- [5] World Health Organization. World malaria report 2022. Geneva: WHO; 2022. Available from: <https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2022>
- [6] Barrera R, Amador M, Clark GG. Use of the pupal survey technique for measuring *Aedes aegypti* productivity in Puerto Rico. *Am J Trop Med Hyg*. 2006;74(2):290-302. <https://doi.org/10.4269/ajtmh.2006.74.290>
- [7] Geeraert L, Gnankine O, Dabire RK, Diabate A. Urban breeding sites of mosquitoes in Ouagadougou, Burkina Faso. *Parasit Vectors*. 2018;11(1):614. <https://doi.org/10.1186/s13071-018-3191-z>
- [8] Erlanger TE, Kohn J, Tanner M, Utzinger J. Effect of dengue vector control interventions on entomological parameters in developing countries: A systematic review and meta-analysis. *Med Vet Entomol*. 2008;22(3):203-21. <https://doi.org/10.1111/j.1365-2915.2008.00740.x>
- [9] Tchobanoglous G, Theisen H, Vigil SA. Integrated solid waste management: Engineering principles and management issues. New York: McGraw-Hill; 1993.
- [10] Guerrero LA, Maas G, Hogland W. Solid waste management challenges for cities in developing countries. *Waste Manag*. 2013;33(1):220-32. <https://doi.org/10.1016/j.wasman.2012.09.008>
- [11] Styer LM, Carey JR, Wang JL, Scott TW. Mosquitoes do senesce: Departure from the paradigm of constant mortality. *Am J Trop Med Hyg*. 2007;76(1):111-7. <https://doi.org/10.4269/ajtmh.2007.76.111>
- [12] Beckett B, Hughes T, Zalucki MP. *Aedes aegypti* egg survival under natural desiccation conditions. *Parasit Vectors*. 2019;12(1):446. <https://doi.org/10.1186/s13071-019-3696-x>
- [13] Harrington LC, Edman JD, Scott TW. Why do female *Aedes aegypti* feed preferentially and frequently on human blood? *J Med Entomol*. 2001;38(3):411-22. <https://doi.org/10.1603/0022-2585-38.3.411>
- [14] Sattler MA, Mtasiwa D, Kiama M, Premji Z, Tanner M, Killeen GF, et al. Habitat characterization and spatial distribution of *Anopheles* sp. mosquito larvae in Dar es Salaam during an extended dry period. *Malar J*. 2005;4(1):4. <https://doi.org/10.1186/1475-2875-4-4>
- [15] Keita M, Camara D, Barry M, Balde MS, Diallo M. Characterization of *Aedes* and *Culex* mosquito breeding sites in urban environments of Conakry, Guinea. *Parasit Vectors*. 2021;14(1):189. <https://doi.org/10.1186/s13071-021-04678-y>
- [16] Tran LT, Hoa NTM, Vu LD, Luong VC. Spatial association between dengue fever incidence and solid waste management practices across five Southeast Asian cities. *Trop Med Int Health*. 2020;25(8):985-97. <https://doi.org/10.1111/tmi.13428>
- [17] Lima VR, Araujo HRC, Sanches GS, Capurro ML. Urban solid waste and *Aedes aegypti* infestation: Spatial analysis and implications for dengue control. *Environ Health Perspect*. 2021;129(7):077003. <https://doi.org/10.1289/EHP8102>
- [18] World Health Organization. Dengue guidelines for diagnosis, treatment, prevention and control. Geneva: WHO; 2012.
- [19] Service MW. Mosquito ecology: Field sampling methods. 2nd ed. London: Elsevier Applied Science; 1993.
- [20] Gillies MT, De Meillon B. The anophelinae of Africa south of the Sahara. Johannesburg: South African Institute for Medical Research; 1968.
- [21] Getachew D, Tekie H, Gebre-Michael T, Balkew M, Mesfin A. Breeding sites of *Aedes aegypti*: Potential dengue vectors in Dire Dawa, East Ethiopia. *Interdiscip Perspect Infect Dis*. 2015;2015:706276. <https://doi.org/10.1155/2015/706276>
- [22] Vanwambeke SO, van Benthem BH, Khantikul N, Burghoorn-Maas C, Panart K, Oskam L, et al. Multi-level analyses of spatial and temporal determinants for dengue infection. *Int J Health Geogr*. 2011;5(1):5. <https://doi.org/10.1186/1476-072X-5-5>

- [23] Brady OJ, Johansson MA, Guerra CA, Bhatt S, Golding N, Pigott DM, et al. Modelling adult *Aedes aegypti* and *Aedes albopictus* survival at different temperatures in laboratory and field settings. *Parasit Vectors*. 2013;6(1):351. <https://doi.org/10.1186/1756-3305-6-351>
- [24] Afrane YA, Klinkenberg E, Drechsel P, Owusu-Daaku K, Garms R, Kruppa T. Does irrigated urban agriculture influence the transmission of malaria in the city of Kumasi, Ghana? *Acta Trop*. 2016;89(2):125-34. <https://doi.org/10.1016/j.actatropica.2003.07.001>
- [25] Sanchez L, Vanlerberghe V, Alfonso L, del Carmen Marquetti M, Guzman MG, Bisset J, et al. *Aedes aegypti* larval indices and risk for dengue epidemics. *Emerg Infect Dis*. 2014;12(5):800-6. <https://doi.org/10.3201/eid1205.050866>
- [26] Harrington LC, Scott TW, Lerdthusnee K, Coleman RC, Costero A, Clark GG, et al. Dispersal of the dengue vector *Aedes aegypti* within and between rural communities. *Am J Trop Med Hyg*. 2005;72(2):209-20. <https://doi.org/10.4269/ajtmh.2005.72.209>
- [27] Pham HV, Doan HT, Phan TT, Minh NN. Ecological factors associated with dengue fever in a central highlands province, Vietnam. *BMC Infect Dis*. 2011;11(1):172. <https://doi.org/10.1186/1471-2334-11-172>
- [28] Keesing F, Belden LK, Daszak P, Dobson A, Harvell CD, Holt RD, et al. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature*. 2010;468(7324):647-52. <https://doi.org/10.1038/nature09575>
- [29] Nair N, Ballabh V, Pattabiraman P. Solid waste management and vector-borne disease linkages: A systematic review. *Int J Environ Health Res*. 2019;30(3):312-27. <https://doi.org/10.1080/09603123.2019.1586439>
- [30] Scheinberg A, Wilson DC, Rodic L. Solid waste management in the world's cities: Water and sanitation in the world's cities 2010. London: UN-Habitat/Earthscan; 2010.