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Container-specific pupal productivity for household dengue vector control: A cross-sectional entomological survey in Antang, Makassar, Indonesia

Produktivitas pupa berdasarkan jenis wadah untuk pengendalian vektor demam berdarah dengue pada rumah tangga: Survei entomologi potong lintang di Antang, Makassar, Indonesia

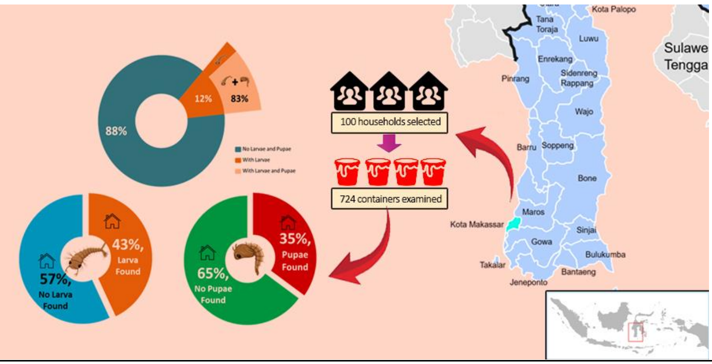
Ruslan La Ane*[1, 2, 3], Wahyulan Amboi[4], Erniwati Ibrahim[5], Andi Susilawaty[6]

[1, 4, 5] Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[2] Graduate School of Science and Engineering, Ehime University, Matsuyama, Japan
[3] Center for Marine Environmental Studies (CMES), Ehime University, Matsuyama, Japan
[6] Magister of Public Health Program, Postgraduates Program, Universitas Islam Negeri Alauddin Makassar, Makassar, Indonesia

Abstract
Recent urban dengue programs increasingly move beyond larval indices, yet many interventions still underuse container-specific pupal productivity to prioritize household breeding habitats. This study quantified which domestic containers contribute most to *Aedes aegypti* pupal output in Antang Village, Makassar, to guide targeted and cost-effective dengue vector control at the family level. A cross-sectional entomological survey was conducted in 100 households selected through proportional multistage sampling. All indoor and outdoor water-holding containers were counted and inspected; larvae and pupae were collected, reared for species confirmation, and analyzed using standard entomological indices and container-specific pupal contributions. Of 724 containers examined, 87 (12%) were larva-positive and 72 (10%) were pupa-positive. The House Index was 43%, the Container Index 12%, and the Breteau Index 87, indicating substantial transmission potential. Pupal production was highly concentrated: buckets (39.92% of containers) accounted for 61.11% of pupae, and bath tanks (6.63%) contributed 18.06%, whereas flowerpots/vases were common (38.26%) but produced only 11.11% of pupae; other container types each contributed ≤4.17%. These findings suggest that stable, longer-retention water habitats disproportionately support development to the pupal stage and likely adult emergence. Targeting household actions to buckets and bath tanks—covering, routine draining and scrubbing, improving water-storage practices, and using larvicide only when emptying is not feasible—should deliver the greatest reduction in adult vectors per unit effort while aligning with Islamic family health values emphasizing cleanliness (*ṭahārah*), prevention of harm, and shared responsibility.

Abstrak
Program-program pengendalian demam berdarah di perkotaan saat ini semakin berkembang lebih dari sekedar penggunaan indeks larva, namun banyak intervensi masih kurang yang memanfaatkan produktivitas pupa pada wadah spesifik sebagai prioritas pengendalian habitat perkembangbiakan vektor di tingkat rumah tangga. Studi ini mengukur wadah yang dapat menampung air mana saja yang paling berkontribusi terhadap produksi pupa *Aedes aegypti* di Kelurahan Antang, Makassar, guna mengarahkan pengendalian vektor demam berdarah yang terarah dan efisien secara biaya di tingkat keluarga. Survei entomologi potong lintang dilakukan di 100 rumah tangga yang dipilih melalui sampling bertahap proporsional. Semua wadah yang dapat menampung air baik di dalam maupun di luar rumah dihitung dan diperiksa; larva dan pupa dikumpulkan, dipelihara hingga dewasa untuk konfirmasi spesies, dan dianalisis menggunakan indeks entomologi standar dan kontribusi pupa spesifik wadah. Dari 724 wadah yang diperiksa, 87 (12%) positif larva dan 72 (10%) positif pupa. Indeks Rumah sebesar 43%, Indeks Wadah 12%, dan Indeks Breteau 87, menunjukkan potensi penularan yang signifikan. Produksi pupa sangat terkonsentrasi: ember (39,92% dari wadah) menyumbang 61,11% pupa, dan bak mandi (6,63%) menyumbang 18,06%, sedangkan pot bunga/vas umum (38,26%) tetapi hanya menghasilkan 11,11% pupa; jenis wadah lain masing-masing menyumbang ≤4,17%. Temuan ini menunjukkan bahwa wadah-wadah yang menampung air yang stabil dan tersimpan lebih lama secara tidak proporsional mendukung perkembangan hingga tahap pupa dan kemungkinan munculnya nyamuk dewasa. Tindakan rumah tangga yang difokuskan pada ember dan bak mandi—menutup, menguras dan menyikat rutin, memperbaiki penyimpanan air, serta menggunakan larvasida bila pengurasan tidak memungkinkan—diperkirakan paling efektif menurunkan jumlah vektor dewasa per unit tindakan, sekaligus selaras dengan nilai Islam tentang kebersihan (*ṭahārah*), pencegahan bahaya, dan tanggung jawab bersama.

Graphical Abstract



Keyword
Aedes aegypti; breeding habitats; dengue; larva; pupa

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Correspondence
Jl. Perintis Kemerdekaan Km.10
Kampus UnhasTamalanrea, Makassar, Sulawesi Selatan, 90245, Indonesia
ruslan.ane@unhas.ac.id

INTRODUCTION

The proliferation of *Aedes aegypti* in urban environments remains a major public health challenge in tropical countries, including Indonesia. As the primary vector of dengue, chikungunya, and Zika, *Aedes aegypti* contributes substantially to preventable morbidity and mortality (World Health Organization [WHO], 2024). Dengue fever, in particular, has become a significant global public health threat due to its widespread transmission, its impact on morbidity and mortality, and its increasing trend in tropical and subtropical regions (Mejía et al., 2023). As of September 2024, global data reported more than 13 million dengue cases, with over 8,500 dengue-related deaths (Nakase et al., 2024). In addition, in January 2026, more than 100,000 dengue cases and over 10 dengue-associated deaths were reported across 39 countries and territories worldwide (European Centre for Disease Prevention and Control, 2026).

This growing burden is closely aligned with the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), which emphasizes the prevention and control of communicable diseases, and SDG 11 (Sustainable Cities and Communities), which highlights the need to reduce health risks in rapidly urbanizing areas. In Indonesia, dengue continues to persist with fluctuating incidence, with a reported resurgence to 52.1 cases per 100,000 population in 2022, suggesting that current urban vector control measures may not yet be sufficiently effective (Kementerian Kesehatan Republik Indonesia, 2022). The urban success of *Aedes aegypti* is further supported by high population density, increased human mobility, and domestic water storage practices, all of which create abundant microhabitats suitable for the development of immature mosquito stages (Dharmamuthuraja et al., 2023; Kolimenakis et al., 2021).

Antang Village in Makassar City illustrates how urban ecology and household practices converge to sustain vector populations. The reported increase in dengue cases over recent years highlights the need to understand local drivers of mosquito proliferation and to refine interventions accordingly (Dinas Kesehatan Kota Makassar, 2020). Water storage behaviors—often adopted to cope with intermittent water supply—encourage use of buckets and bath tanks that can become persistent breeding habitats when left uncovered or infrequently cleaned (Trewin et al., 2021; Zanoni et al., 2025). In parallel, inadequate waste management can result in discarded items that retain rainwater and support larval development (Allman et al., 2022; Pereira et al., 2024). Taken together, these conditions create a complex, household-centered risk environment requiring localized evidence to identify which containers contribute most to adult mosquito emergence and transmission potential.

Despite recognition that *Aedes aegypti* breeds in a wide range of domestic and peri-domestic containers, many control programs still rely on broad approaches (e.g., general education and insecticide spraying) that may be inefficient if they do not prioritize the most productive breeding habitats (Mulderij-Jansen et al., 2022). The diversity and sheer number of potential containers in dense urban settings complicate operational targeting (Duval et al., 2023), while socio-economic constraints can limit sustained household participation (Hossain et al., 2024). A more effective general solution is to shift from indiscriminate container-focused actions toward a productivity-based prioritization strategy that identifies and targets the container types most responsible for producing pupae, a closer proxy for adult mosquito emergence and disease risk than larval presence alone.

Scientific literature indicates that *Aedes aegypti* thrives in human-dominated environments and exploits container types shaped by everyday household routines. The mosquito can breed in water storage containers, flowerpots, gutters, and discarded tires, making control difficult when interventions are not linked to container ecology and use patterns (Dalpadado et al., 2022; Pinchoff et al., 2021; Prasad et al., 2023). Open-mouthed containers, including buckets and tires, are repeatedly implicated because they collect water, are frequently left uncovered, and can remain wet long enough to support complete development (Mataba et al., 2022; Pinchoff et al., 2021). Microenvironmental conditions also matter: containers placed in shaded locations may provide cooler, more stable conditions that improve larval survival and development (Qureshi et al., 2023).

Although studies in Indonesia have shown that mosquito abundance is strongly influenced by habitat characteristics and local environmental conditions, evidence identifying which household containers contribute disproportionately to *Aedes* pupal production remains limited. Research from Bandar Lampung, West Jakarta, and Central Bengkulu has highlighted the importance of larval habitat preference and ecological determinants, including water quality, light intensity, proximity to buildings, and predator presence, in shaping mosquito distribution and density (Nurjanah et al., 2023; Kermelita et al., 2024; Novianto et al., 2025; Yulwiyandari et al., 2025). However, these studies have primarily focused on habitat ecology, species occurrence, or larval density rather than on quantifying pupal productivity by container type at the household level. This distinction is critical, because pupal indices provide a closer approximation of adult mosquito emergence and, therefore, a more operationally relevant basis for dengue vector control.

Evidence from other settings further suggests that container productivity is not determined by container presence alone, but by a combination of physical and behavioral factors, such as water retention, habitat stability, sunlight exposure, and the frequency of human disturbance (Multini et al., 2021; Ouédraogo et al., 2022). While previous studies have mapped breeding-site occurrence across multiple container types (Mataba et al., 2022; Ouédraogo et al., 2022; Prasad et al., 2023; Zanoni et al., 2025), far fewer have assessed which containers consistently produce the greatest number of pupae. This gap is particularly important in high-density urban communities, where socio-economic heterogeneity shapes container availability, use, and maintenance, and where simple breeding-site positivity may not reflect true epidemiological importance (Herath et al., 2024; Zettle et al., 2022). Moreover, limited attention has been given to the interaction between environmental conditions and household practices, such as draining, covering, and scrubbing, in determining why some containers remain persistently productive. As a result, routine control programs may disperse effort across too many container types without clear evidence of priority. Taken together, the literature underscores the need for container-specific assessment of pupal productivity to identify the most epidemiologically important household habitats and to improve the precision and impact of dengue vector control.

Addressing this gap, the novelty of the present study lies in applying container-specific pupal contribution to identify the most productive household breeding habitats for control prioritization. The study aims to identify and quantify the most productive Aedes aegypti breeding habitats in Antang Village, Makassar, and to assess how container characteristics and household water-storage practices shape their productivity. The findings are expected to generate operationally relevant evidence to strengthen more targeted household-based dengue vector control in urban settings.

METHODS

Study design and period

This study employed an observational, descriptive cross-sectional design to identify and quantify household container types that contribute most to *Aedes aegypti* pupal production. Field data collection was conducted from May to June 2022.

Study setting

The study was carried out in Antang Village, Manggala Sub-district, Makassar, Indonesia. Antang is a densely populated urban area consisting of seven community groups (Rukun Warga/RW) and 42 neighborhood units (Rukun Tetangga/RT), with a total of 2,567 households. The urban household environment and diversity of water-holding containers in this village provide a relevant setting to assess container-specific productivity for dengue vector control.

Study population, sample size, and sampling technique

The study population comprised all households in Antang Village (N = 2,567). A total of 100 households were selected using multistage stratified random sampling with proportional allocation by household density. First, the village was stratified by RW and RT to ensure coverage of all administrative clusters. Second, within each RT, households were listed and randomly selected using a random number generator. Third, the number of households sampled from each stratum was allocated proportionally to the total households in that RW/RT to maintain representativeness across high- and low-density areas.

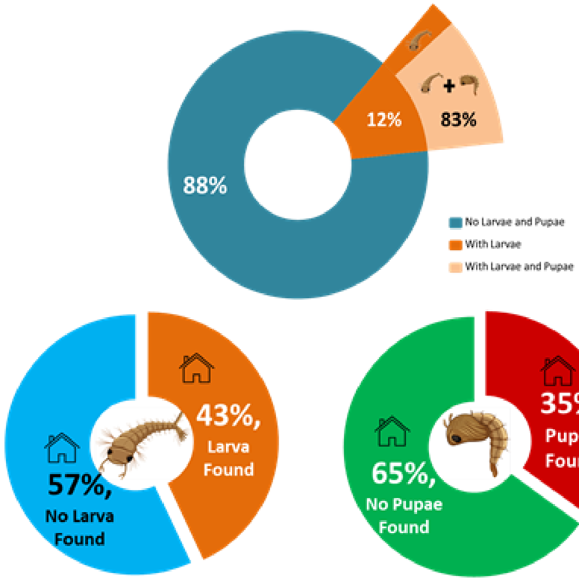
Eligibility criteria

Households were eligible if they were located in the selected RT strata, had an adult household member available to provide informed consent, and allowed inspection of indoor and outdoor areas. Households were excluded if consent was not provided or if access to key household areas and water-holding containers could not be obtained at the time of visit.

Research procedures and data collection

After obtaining consent, trained surveyors conducted standardized household-based entomological inspections of both indoor and outdoor environments. All water-holding containers capable of retaining water were identified, enumerated, and

Figure 1
Proportion of Ae. aegypti breeding habitats and their distribution in inspected households



assigned unique codes. Container characteristics were recorded, including container type (e.g., buckets, bath tanks, flowerpots/vases, gutters, and other artificial receptacles), location (indoor/outdoor), and observable environmental conditions relevant to mosquito development (e.g., exposure and water retention).

Each container was visually examined for larvae and pupae using a flashlight and appropriate collection tools (dipper or pipette). Containers were categorized as positive or negative for larvae and pupae. For each positive container, three to five larvae and/or pupae were collected to reduce loss from mortality during transport and to ensure sufficient specimens for identification. Samples were placed in labeled containers indicating household code, container type, and container location, then transported to the Entomology–Parasitology Laboratory, Faculty of Medicine, Hasanuddin University.

Laboratory procedures and species confirmation

In the laboratory, collected larvae and pupae were reared to the adult stage under controlled conditions. Adult mosquitoes were identified morphologically using standard identification keys. Identification was performed using a stereomicroscope (0.67×–5× magnification). Adult specimens were euthanized using chloroform vapor, and species confirmation was used to verify that specimens were *Aedes aegypti*.

Data analysis and presentation

Data were analyzed to characterize breeding-site distribution and to quantify container-specific pupal productivity. Standard entomological indices were calculated: House Index (HI; percentage of houses with ≥1 positive container), Container Index (CI; percentage of containers positive for larvae or pupae), and Breteau Index (BI; number of positive containers per 100 houses). A Pupae Index (PI; percentage of containers containing pupae) was also computed to emphasize habitats most associated with adult emergence potential. A Density Figure (DF) was derived using World Health Organization guidance to categorize transmission risk; DF values >5 were interpreted as high risk (WHO, 2011).

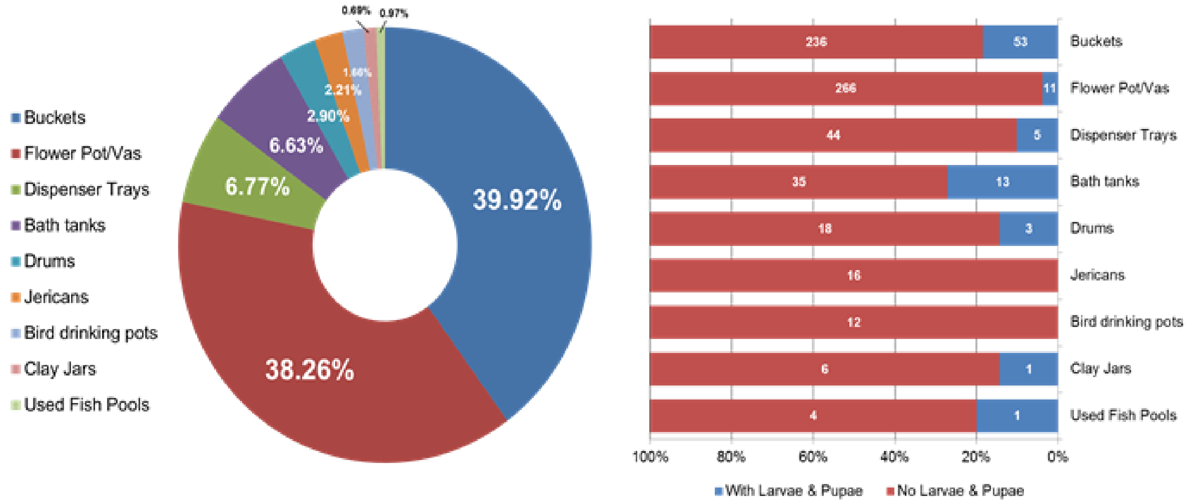
To identify high-priority breeding sites, the total number of pupae from each container type was summed and expressed as a relative contribution (%) to overall pupal output in the study area. Container types with the largest proportional contributions were designated as priority targets for intervention.

Results were presented descriptively using frequencies and percentages of container types, positivity rates (larva-positive and pupa-positive), and contributions of each container type to total pupae. Indices (HI, CI, BI, PI) and DF classifications were reported to contextualize transmission risk.

Ethical considerations and informed consent

Ethical clearance for this study was formally granted by the Health Research Ethics Committee of the Faculty of Public Health, Hasanuddin University,

Figure 2
Proportion of Aedes aegypti Breeding Site



under the recommendation letter number 348/UN4.14.1/TP.01.02/2022. The research was conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki regarding research involving human subjects. Prior to the commencement of field activities, administrative authorization was secured from the local government authorities of Antang Village and the Manggala sub-district. Informed consent was obtained from the head of each participating household after a comprehensive explanation of the survey's purpose and procedures. To protect participant privacy, all household data were anonymized, and confidentiality was rigorously maintained throughout the data analysis and reporting stages.

RESULTS

The entomological survey conducted in Antang Village revealed a total of 724 potential *Aedes aegypti* breeding sites across 100 randomly selected households. These breeding habitats included various types of containers, both indoors and outdoors, which can hold stagnant water conducive to mosquito breeding. Of the 724 containers surveyed, 87 (12%) were found to harbor *Aedes aegypti* larvae, while 72 (10%) contained pupae, indicating substantial mosquito breeding activity across surveyed households (See Figure 1). Larval and pupal positive containers were distributed across 43 households, suggesting that nearly half of the surveyed households supported active mosquito breeding habitats.

Several entomological indices were calculated to assess the density and prevalence of *Aedes aegypti* breeding within the area. House Index (HI) represents the percentage of houses infested with larvae and/or pupae. In this study, HI was calculated at 43%, indicating that nearly half of the surveyed households had active breeding sites. Container Index (CI) denotes the percentage of water-holding containers infested with larvae or pupae. The CI was 12%, meaning that 12% of all inspected containers were positive for *Aedes aegypti*. Breteau Index (BI) calculated as the number of positive containers per 100 houses inspected. A BI of 87 suggests a high density of breeding sites relative to the number of households. Pupae Index (PI) indicates the percentage of containers containing pupae, which are the life stage directly preceding adulthood. The PI was 10%, signifying that a substantial proportion of positive containers had the potential to contribute to the adult mosquito population.

These indices are critical for gauging the risk of dengue transmission, as higher values correlate with increased mosquito abundance and, consequently, a greater potential for disease spread. According to the WHO (2011), a Breteau Index (BI) above 50 or a House Index (HI) above 5% signifies a high-risk transmission area. Therefore, Antang Village, with an HI of 43% and a BI of 87, is categorized as a significant site for vector proliferation.

Distribution of Larval and Pupal Positive Containers

In this survey, nine types of *Aedes aegypti* mosquito breeding habitats were identified in the surveyed households. The most common container types were buckets accounted for 289 (39.92%), flowerpots 277 (38.26%), and bath tanks 48 (6.63%), followed by less prevalent types such as dispenser

Table 1
Pupae contribution by type of breeding sites

Breeding Site	Number of Breeding Sites	Pupa count	Contribution (%)
Buckets	289	44	61.11
Bath tanks	48	13	18.06
Flowerpots/vases	277	8	11.11
Drums	21	3	4.17
Dispenser trays	49	2	2.78
Used fish pools	5	1	1.39
Clay jars	7	1	1.39
Jericans	16	0	0
Birds drinking pots	12	0	0

Note: Total number of breeding sites = 724; Total pupae count = 72

trays and drums and clay jars (See Figure 2). This distribution demonstrates the adaptability of *Aedes aegypti* to multiple artificial breeding sites, consistent with previous studies that highlight the mosquito's preference for human-related environments.

Among the various types of breeding sites, buckets were the most frequently found habitats containing *Aedes aegypti* larvae, with a total of 53 instances (7.32%). This was followed by bath tanks, with 13 instances (1.80%). In contrast, the habitats with the fewest larvae were abandoned fish tanks/aquariums and clay jars, each found to contain only 1 instance (0.14%). In addition to larvae presence, pupae were also observed, with the highest number found in buckets, totaling 44 (6.08%), followed by bath tanks with 13 (1.80%) and flowerpots/vases with 8 (1.10%).

Analysis of Breeding Site Productivity

This study analyzed container productivity based on pupae counts, as pupa abundance serves as a critical indicator of habitat productivity in terms of mosquito population growth. Results show that buckets are the most productive breeding sites, contributing 61.11% of total pupae found across all surveyed containers. Bath tanks, while less prevalent than buckets, accounted for 18.06% of pupae, making them the second-highest contributor to mosquito productivity. Flowerpots, despite their abundance in surveyed households, contributed only 11.11% to total pupae counts. Other container types, including drums and dispenser trays, showed minimal productivity, with pupal contributions ranging from 1.39% to 4.17% (See Table 1).

This distribution suggests that buckets and Bath tanks are particularly conducive to mosquito proliferation, likely due to their water stability and retention properties, which support prolonged mosquito development cycles. In contrast, flowerpots and other smaller containers may have reduced productivity due to environmental factors like periodic drying or exposure to sunlight.

DISCUSSION

This study provides important insights into the breeding ecology of *Aedes aegypti* in an urban setting in Antang Village, Makassar, by identifying the household containers that contribute most to vector productivity. The findings show that buckets and bath tanks were the most productive breeding sites, indicating that stable domestic water-storage containers play a central role in sustaining mosquito populations. These results strengthen existing understanding that *Aedes aegypti* breeding is strongly shaped by the interaction between household behavior, container characteristics, and local environmental conditions, and they provide operationally relevant evidence for more targeted vector control in urban communities.

Breeding sites were found both indoors and outdoors across surveyed households. Indoor breeding habitats, mainly located in bathrooms and storage areas, were dominated by buckets and bath tanks, whereas outdoor habitats included flowerpots, drums, and other water-holding containers exposed to environmental conditions. This distribution suggests that although *Aedes aegypti* is commonly associated with indoor domestic environments, productive breeding also occurs outdoors. Therefore, effective mosquito control should not be limited to indoor water-storage containers alone, but should also address outdoor habitats that may contribute to continued vector persistence (Lenhart et al., 2022).

The higher productivity of buckets and bath tanks can be explained by several environmental and structural characteristics, particularly water retention, habitat stability, and the degree of household disturbance. These containers are able to retain water for prolonged periods, creating a stable aquatic environment that allows immature mosquitoes to complete their development cycle with minimal interruption. This pattern is consistent with work of Dalpadado et al. (2022) emphasizing the importance of water availability and habitat stability in determining breeding-site productivity. In contrast, smaller containers such as flowerpots, although frequently present, are more vulnerable to drying, sunlight exposure, and repeated disturbance through household use or changing outdoor conditions. As a result, their contribution to mosquito production appears to be lower despite their abundance. Taken together, these findings suggest that container productivity is determined not only by the presence of water-holding habitats, but also by the extent to which those habitats provide stable conditions for successful mosquito development (Mbanzulu et al., 2022).

The study found that human usage patterns influence container productivity, particularly for household water-storage containers. In many urban settings, tanks/drums and, in some contexts, buckets used for routine water storage are cleaned or emptied infrequently, enabling mosquitoes to complete breeding with minimal disturbance (Waewwab et al., 2020). Studies from Southeast Asia similarly document that household practices and container management shape the availability of *Aedes aegypti* breeding sites (Agus Nurjana et al., 2023; Sahavechaphan et al., 2024). In urban areas like Antang (Makassar), where residents often store water due to intermittent supplies, these practices likely contribute to high container productivity, underscoring the need for vector control programs to address both container characteristics and the socio-economic drivers of water storage (La Ane et al., 2021).

The identification of buckets and bath tanks as high-productivity breeding sites has significant implications for vector control strategies in urban settings (Rahman et al., 2021). Traditional control approaches that target all potential breeding sites equally may be insufficient if they fail to prioritize containers with high mosquito productivity. This study highlights the importance of targeted interventions that focus specifically on high-yield containers, potentially enhancing the effectiveness of mosquito control programs. By concentrating resources on cleaning, draining, and treating buckets and bath tanks, public health initiatives can achieve more substantial reductions in mosquito populations and, consequently, a lower risk of disease transmission (Muthusamy et al., 2025).

Furthermore, this study supports the growing body of literature advocating for behaviorally-informed vector control strategies. Recognizing that household practices like water storage in buckets and bath tanks contribute to mosquito proliferation, public health campaigns can focus on educating communities about proper water management. For example, encouraging households to empty and clean water containers regularly, cover stored water, or use alternative storage methods could significantly reduce mosquito breeding opportunities. Community-based educational initiatives have proven effective in other Southeast Asian countries, where changes in household practices led to measurable decreases in mosquito densities and disease incidence (Arfan et al., 2023; Yulfi et al., 2025). Therefore, integrating educational outreach with targeted control measures could enhance the sustainability and impact of vector control efforts in urban areas like Antang Village.

This study contributes empirical evidence on the breeding preferences of Aedes aegypti in Indonesian urban environments. Previous studies have shown that mosquito abundance and breeding-site suitability are shaped by habitat characteristics and environmental conditions, including water quality, light intensity, and proximity to human dwellings (Nurjanah et al., 2023; Novianto et al., 2025; Yulwiyandari et al., 2025). It expands understanding of how specific container types contribute to mosquito productivity and emphasizes the role of stable water sources in urban mosquito breeding ecology. By focusing on high-productivity breeding sites, this research refines existing mosquito control strategies and offers data-driven insights that can be applied in other urban contexts with similar environmental and socio-economic conditions.

The findings also have broader implications for vector control policy and program design, especially in densely populated urban areas where traditional approaches may be less effective. The clear association between container stability, water retention, and mosquito productivity highlighted in this study suggests that future vector control policies should incorporate targeted interventions as a core component of their strategy. This approach aligns with international recommendations for integrated vector management, which advocates for a combination of targeted control, community engagement, and environmental management to achieve sustainable mosquito population reductions (WHO, 2011).

The effectiveness of container-focused interventions may be enhanced by integrating Islamic family health values that emphasize cleanliness, prevention, and collective responsibility. Household water management is closely aligned with the concept of *ṭahārah* (cleanliness and purity), which encourages the maintenance of a hygienic domestic environment, particularly in areas related to water use and storage (Angelakis et al., 2023) . This perspective is consistent with Qur'anic teachings in Surah Al-Baqarah/2:222, that emphasize purification as an important moral principle:

> *"... Indeed, Allah loves those who are constantly repentant and loves those who purify themselves."*

In this context, cleanliness can be understood not only as a personal virtue but also as a foundation for health-promoting behavior. Regular draining and scrubbing of buckets and bath tanks also reflect the principle of preventing harm (*dar' al-mafāsid*), as such practices eliminate environmental conditions that enable mosquito breeding and disease transmission (Irfan et al., 2025). Moreover, dengue prevention is consistent with the broader Islamic objectives of promoting public welfare (*maslahah*) and fostering mutual cooperation within the community, as reflected in the following Qur'anic guidance in Surah Al-Ma'idah/5:2:

> *"... And cooperate in righteousness and piety, but do not cooperate in sin and aggression ..."*

Framing household vector control within religion values may improve community acceptance and encourage sustained behavioral change, positioning dengue prevention not merely as a technical activity but also as a family-centered moral responsibility embedded in daily life (Arham et al., 2021; Shafie et al., 2023).

One of the strengths of this study lies in its methodical approach to identifying and analyzing high-productivity breeding sites. By using a systematic sampling method and focusing on entomological indices relevant to public health, this research provides robust, context-specific insights that can inform local vector control strategies. Additionally, the study's focus on a densely populated urban area with diverse container types allows for a comprehensive analysis of *Aedes aegypti* breeding patterns, enhancing the relevance of findings for urban vector control programs.

However, several limitations of this study should be acknowledged. First, the survey was conducted during a specific season, which may have influenced the availability and productivity of particular breeding sites. Seasonal variation in rainfall, temperature, and humidity is known to affect mosquito breeding dynamics, and therefore the findings may not fully represent patterns observed throughout the year. A longitudinal design covering multiple seasons would provide a more comprehensive understanding of *Aedes aegypti* breeding site productivity over time. Second, this study was limited to one urban area in Makassar, Indonesia. Although the findings may be relevant to other urban settings with similar environmental and household conditions, caution is needed in extending these results to rural or peri-urban areas, where container types, water-storage practices, and ecological contexts may differ. Including multiple study sites across urban and non-urban settings would improve the external validity of the findings and allow comparison of breeding patterns across different socio-economic and environmental contexts.

These limitations also point to several priorities for future research. Studies conducted across different seasons are needed to clarify how temporal changes in rainfall and temperature influence the productivity of *Aedes aegypti* breeding habitats and to identify periods of heightened vector risk. In addition, spatial analysis of breeding site distribution could provide deeper insight into the ecological drivers of mosquito abundance by linking habitat location with relevant environmental variables. Such an approach may support the development of predictive models for mosquito population increases and help guide more proactive vector control planning. Future studies should also evaluate the effectiveness of targeted interventions directed at highly productive containers over time. Longitudinal assessments of measures such as regular cleaning, draining, or management of buckets and bath tanks would generate stronger empirical evidence on the impact of container-focused control strategies. In parallel, further research should examine household and community responses to these interventions in order to assess their sustainability, acceptability, and potential for wider implementation.

CONCLUSIONS

This study demonstrates that Aedes aegypti breeding in Antang Village, Makassar is driven disproportionately by a limited number of stable household water-storage containers, particularly buckets and bath tanks. Their high pupal productivity highlights that dengue vector control efforts will be more effective when they prioritize "high-yield" habitats rather than treating all potential containers equally. By focusing household actions on covering openings, implementing routine draining and scrubbing, improving water-storage practices, and applying larvicide only when emptying is not feasible, programs can achieve greater reductions in adult mosquito emergence per unit effort, strengthening family-level prevention and supporting sustainable urban dengue control.

These findings contribute to the evidence base for localized, productivity-based container prioritization as a practical decision metric for resource allocation, monitoring, and evaluation in densely populated urban areas. Nevertheless, the cross-sectional design and single-season observation may not capture seasonal shifts in breeding ecology, and results from one village should be generalized cautiously to settings with different water access, housing patterns, or container use. Future research should incorporate multi-season or longitudinal designs, spatial mapping of productive containers, and intervention trials targeting buckets and bath tanks to quantify sustained impacts on pupal output, adult density, and dengue risk.

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AUTHORS' CONTRIBUTIONS

Ruslan La Ane contributed to designing the study, formulating the research concept, writing and reviewing the manuscript, enrolling participants, collecting and acquiring data, and analyzing the data. Wahyulan Amboi contributed to writing the manuscript, collecting and acquiring data, analyzing the data, and performing the fieldwork. Erniwati Ibrahim contributed to designing the study, formulating the research concept, and reviewing the manuscript. Andi Susilawaty contributed to writing and reviewing the manuscript, acquiring and analyzing the data, and revising the manuscript.

AUTHORS' INFORMATION

Ruslan La Ane is a researcher affiliated with the Graduate School of Science and Engineering, Ehime University, Matsuyama, Japan, and the Center for Marine Environmental Studies (CMES), Ehime University, Matsuyama, Japan, and he is also a senior lecturer in Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Wahyulan Amboi is a researcher in Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Erniwati Ibrahim is an associate professor in Department of Environmental Health, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia. Andi Susilawaty is a full professor at the Magister of Public Health Program, Postgraduates Program, Universitas Islam Negeri Alauddin, Makassar, Indonesia.

COMPETING INTERESTS

The author(s) declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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