



Original Article

**Density of *Aedes aegypti* Larvae as Influenced by Abandoned Unwanted Containers: A Review**

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Submitted: September 2025; Accepted: October 2025; Published: December 2025

**SUMMARY**

*Aedes aegypti* remains one of the most efficient vectors of arboviral diseases globally, and its dependence on artificial containers has intensified with rapid urbanization and poor waste management practices. This review synthesizes contemporary evidence on how abandoned and unwanted containers influence larval density, highlighting ecological suitability, container-specific productivity, human behavioural factors, and broader public health implications. Recent studies consistently demonstrate that small, shaded, water-holding debris particularly discarded tires, plastic vessels, and domestic waste serve as the most productive larval habitats, sustaining high mosquito densities even in dry seasons. By integrating findings across entomological, environmental-health, and urban-ecology research, this review emphasizes the central role of container management in vector control. It concludes with a conceptual model and identifies key gaps requiring further scientific exploration.

**Keywords:** *Aedes aegypti*, larval density, abandoned containers, vector ecology, dengue, urban sanitation, artificial habitats

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**INTRODUCTION**

Mosquito-borne diseases such as dengue, Zika, chikungunya, and yellow fever continue to shape global public-health priorities, especially in tropical regions where *Aedes aegypti* thrives. Over the last decade, research has increasingly emphasized that the success of *Aedes aegypti* as a vector is tightly connected to how human communities generate and

manage waste. Unlike many mosquito species that rely on large natural water bodies, *Aedes aegypti* has evolved to exploit small, stagnant water pockets created by human activity. Abandoned and unwanted containers ranging from used tires and cans to household plastics and broken appliances offer ideal microhabitats that support egg laying, larval development, and adult emergence.

Recent work highlights that these containers are more than simple water reservoirs; they act as ecological amplifiers that dramatically increase local mosquito populations. Studies by Ndenga *et al.* [1] and Eneh *et al.* [2] show that container-rich environments can sustain *Aedes* populations even in the absence of consistent rainfall because the eggs remain viable for months in dry conditions. This resilience has contributed to the expansion of arboviral outbreaks in rapidly urbanizing regions.

The challenge is particularly severe in low-resource communities where poor waste disposal systems, irregular sanitation services, and limited awareness lead to an accumulation of water-holding objects around homes. As urbanization accelerates, these abandoned containers often unnoticed or ignored have become the backbone of vector proliferation. Scholars such as Keum *et al.* [3] and Hustedt *et al.* [4] note that microhabitats created by human waste now produce more *Aedes* larvae than natural breeding sites in many tropical cities.

Understanding how container characteristics, environmental factors, and human behaviour interact to influence larval density is essential for designing sustainable vector-control strategies. This review aims to provide an integrated, up-to-date examination of these relationships while identifying scientific gaps that can guide future entomological and public health research.

### **Ecology and Behavioural Adaptations of *Aedes aegypti***

The remarkable success of *Aedes aegypti* as a global vector is rooted in its unique ecological and behavioural traits, many of which position abandoned containers as prime larval development sites. Unlike

other mosquito species that depend heavily on natural aquatic environments, *Aedes aegypti* has evolved into a highly synanthropic organism one that lives in close association with human settlements and relies on human-generated microhabitats for survival. This ecological flexibility is central to understanding why discarded containers sustain such high larval densities.

### **Adaptation to Urban Environments**

Modern urban landscapes provide an almost endless supply of artificial water-holding materials. Over time, *Aedes aegypti* has shifted from natural tree holes to man-made containers, a transition widely documented in recent ecological studies. According to Abreu *et al.* [5], urban environments now support some of the densest *Aedes aegypti* populations globally, primarily due to the abundance of discarded items capable of retaining rainwater. These habitats mimic natural breeding sites but offer even greater stability because they are sheltered, shaded, and less vulnerable to predators.

This urban preference is reinforced by the mosquito's feeding behavior. Female *Aedes aegypti* mosquitoes are highly anthropophilic preferring human blood over that of animals. They often rest and breed in or around homes, meaning any abandoned container near domestic spaces becomes an immediate ecological asset [6].

### **Egg Resilience and Microhabitat Use**

One of the most powerful ecological adaptations of *Aedes aegypti* is the ability of its eggs to withstand desiccation for extended periods. When females lay eggs along the inner walls of a container, those eggs can remain viable even when the container becomes completely dry.

Research by Oliveira-Lima *et al.* [7] found that eggs can retain viability for up to 240 days under typical field conditions.

This biological resilience explains why even dry abandoned containers pose significant risk: as soon as rainwater collects, massive hatching events can occur within hours. Containers thus become long-term ecological “time bombs” even when visually dry or empty.

### Larval Development in Container Microhabitats

- *Aedes aegypti* larvae thrive in small, nutrient-rich water bodies where competition and predation are minimal. Abandoned containers create such microhabitats naturally. Studies by Cromwell *et al.* [8] show that immature stages develop faster in confined, warm, stable environments like plastic buckets, cans, and tires than in natural habitats.

Several container characteristics directly influence larval performance:

- **Temperature:** Small containers heat quickly, accelerating larval growth [9].
- **Shade:** Shaded containers reduce evaporation and overheating, leading to higher larval survival [9].
- **Organic matter:** Leaves, soil, and microbial films provide nutrition essential for larval development [10].

These microhabitats enhance survival rates and shorten the developmental cycle, allowing mosquito populations to grow rapidly.

### Behavioural Traits That Favour Container Breeding

Beyond ecological factors, *Aedes aegypti* demonstrates several behavioral tendencies that directly support container-based breeding:

- **Skip Oviposition:** Females distribute their eggs across multiple containers, a strategy that increases survival by diversifying risk [11].
- **Indoor and peri-domestic resting:** This drives females to seek containers near or inside homes, making household waste extremely significant [12].
- **Selective oviposition:** Females prefer containers with dark surfaces, organic odor profiles, and prior larval presence all of which are commonly found in neglected waste items.

These behaviors ensure that containers, even those holding small amounts of water, are consistently exploited.

### Implications of Ecological Adaptations

The ecological and behavioural adaptations of *Aedes aegypti* create a scenario where abandoned containers act as reproductive hubs capable of sustaining entire mosquito populations. The mosquito’s ability to exploit these microhabitats means that vector control strategies must extend beyond chemical interventions to include environmental, behavioural, and community-level changes. The close ecological match between *Aedes aegypti* and container habitats confirms that any community with indiscriminate waste disposal practices faces elevated vector-borne disease risk.

## Ecology and Behaviour of *Aedes aegypti*

*Aedes aegypti* has evolved as one of the most successful urban mosquitoes in the world. Its behaviour, breeding patterns, and ecological preferences make it uniquely suited to thrive around human settlements. Understanding these characteristics is essential for explaining why abandoned containers remain such powerful drivers of mosquito proliferation.

### Adaptation to Human Environments

*Aedes aegypti* is highly anthropophilic it prefers living near humans and feeding almost exclusively on human blood. Studies show that this species has genetically adapted to urban environments where artificial containers provide ideal breeding sites [13]. Instead of depending on natural tree holes, *Aedes aegypti* now exploits human-generated habitats such as buckets, tires, plastic bottles, and cement tanks [14].

This close association with humans means the mosquito often breeds, feeds, and rests within a very small radius. According to Moyes *et al.* [15], *A. aegypti* rarely disperses more than 100 meters from its breeding site, which helps maintain high local densities in neighbourhoods where containers accumulate.

### 4.2 Reproduction and Life Cycle

The species thrives in small water-holding containers because its eggs are remarkably resilient. Females lay eggs just above the waterline, where they can survive desiccation for months even in harsh dry seasons [16]. Once water fills the container, these eggs hatch rapidly, allowing *A. aegypti* populations to rebound following rains or household water activities.

Larvae feed on the organic matter and microorganisms that accumulate naturally inside abandoned containers. These sites often provide warmer water, rich nutrients, and fewer predators, conditions linked to faster larval development and higher survival [17].

### 4.3 Daytime Biting Activity

Unlike many mosquitoes that are most active at dawn or dusk, *Aedes aegypti* is a **day-biting** species. Its peak feeding windows (mid-morning and late afternoon) coincide with periods when humans are active, which increases biting frequency and disease transmission [18].

This behavioural trait makes environmental control such as container removal far more important than nighttime interventions like bed nets.

### Climate Sensitivity

Climate factors such as temperature, humidity, and rainfall strongly influence population densities. Warmer temperatures accelerate larval development and increase feeding rates in adults [19]. The combination of climate variability and abundant containers has been strongly associated with periodic dengue outbreaks in many tropical countries.

### Ecological Fit to Abandoned Containers

In summary, the mosquito's ecological traits make abandoned containers the perfect breeding environment because these items:

- Hold small, clean or lightly polluted water
- Provide shade and stable temperature
- Are often neglected for long periods

- Occur in high numbers around homes
- Allow egg desiccation and reactivation after rain

These characteristics explain the repeated finding that container-breeding habitats are the strongest predictors of *Aedes aegypti* larval density in urban areas.

### Abandoned and Unwanted Containers as Breeding Sites

Abandoned and unused containers represent the most important man-made ecological niche supporting *Aedes aegypti* proliferation in urban and peri-urban environments. Their abundance, diversity, and ability to retain clean or stagnant water create perfect microhabitats for larval development. Research across multiple tropical regions consistently shows that container-rich environments record the highest mosquito densities and disease transmission risk.

### Why Containers Are Ideal Breeding Sites

From an ecological perspective, abandoned containers meet nearly all the biological requirements of *A. aegypti*. These containers, which include tires, buckets, cans, paint containers, plastic bottles, and discarded household items, typically accumulate water from rain, leaking pipes, or domestic activities. According to Ndenga *et al.* [1], *Aedes aegypti* prefers containers because they:

- Hold small volumes of water with low turbulence
- Offer protection from predators
- Create warm, nutrient-rich environments
- Are commonly found near human dwellings

Studies in Brazil, Nigeria, India, and Southeast Asia have shown that these factors significantly increase larval survivorship and adult emergence rates [20,21].

### Types of Containers Commonly Implicated

Different types of containers support larval development to varying degrees. Research consistently identifies discarded tires as the most productive breeding sites because they retain water for long periods, experience stable temperatures, and accumulate organic debris [22].

Other highly productive containers include:

- Plastic buckets and bowls
- Bottles and cans
- Water storage tanks
- Paint buckets and plastics
- Flower pots and trays
- Cement tanks and roof gutters

In many West African cities, including Lagos and Accra, household water storage containers have become major larval sources due to irregular water supply, forcing residents to store water in drums and buckets [23].

### Container Characteristics Influencing Larval Density

Not all containers contribute equally. Specific container characteristics influence larval productivity:

1. **Size & Shape:** Larger surface area supports more oxygen exchange, which larvae need.
2. **Material:** Plastic and rubber retain heat, accelerating larval development [17].

3. **Shading:** Shaded containers produce more larvae than those in direct sunlight because overheating can kill larvae [24].
4. **Water Quality:** *A. aegypti* prefers clean to lightly polluted water rich in microorganisms.
5. **Duration of Water Retention:** Containers that hold water for more than 5–7 days become highly productive breeding sites.

### Human Practices That Increase Container Abundance

The issue of abandoned containers is primarily a human-made problem. Urbanization, poor waste management, and socio-economic conditions allow containers to accumulate rapidly. For instance:

- Poor disposal of plastic waste
- Lack of municipal waste collection
- Storage of unused household items
- Water scarcity leading to widespread water storage
- Construction debris left on sites
- Indiscriminate dumping in residential areas

These factors create a continuous supply of water-holding containers. A study in Kenya demonstrated that households with poor waste disposal practices had three times higher mosquito larval densities than cleaner households [24].

### Seasonal Influence on Container Productivity

During the rainy season, container productivity increases sharply because rainfall fills even the smallest discarded

items. This is supported by evidence from Southeast Asia and West Africa showing a spike in dengue transmission following heavy rains [21]. Dry seasons do not eliminate risk either, as *A. aegypti* eggs survive months without water, reactivating when the next rains arrive.

### Evidence Linking Containers to Increased Larval Density

By combining field entomological surveys and statistical modelling, researchers have documented a strong positive correlation between container density and mosquito infestation. For example:

- A 2022 study in Brazil found that **over 80%** of all *A. aegypti* larvae were recovered from abandoned plastic containers and tires [25].
- In Malaysia, container index and Breteau index increased significantly in areas with poor waste management [26].
- In Nigeria, urban settlements with high container accumulation recorded **twice the larval density** of cleaner neighbourhoods [23].

### Influence of Abandoned Containers on *Aedes aegypti* Larval Density

The density of *Aedes aegypti* larvae is strongly shaped by the presence, abundance, and characteristics of abandoned containers within residential and peri-urban environments. A wealth of entomological studies across Africa, Asia, and the Americas has shown that the productivity of these containers directly predicts mosquito infestation levels, adult emergence rates, and ultimately, disease transmission. This section synthesizes recent evidence to explain how containers shape larval density patterns.

## **Mechanisms Through Which Containers Increase Larval Density**

Abandoned containers create a unique micro-ecological system that allows mosquito larvae to thrive. The key mechanisms include:

### **1. Stable Water Accumulation**

Containers accumulate rainwater or domestic water and retain it for long periods. This provides an uninterrupted aquatic habitat for larval development. According to Rahim *et al.* [26], containers that retain water for more than 7 days are 4–6 times more productive than those with intermittent water.

### **2. Absence of Predators**

Natural habitats such as ponds and streams contain predators like copepods and fish. Containers, in contrast, lack such predators, creating a survival advantage for mosquito larvae (Achee *et al.*, 2019).

### **3. Temperature Regulation**

Rubber, plastic, and metal containers retain heat, increasing water temperature slightly above ambient levels. Warmer water accelerates larval growth, reducing development time from 10 days to as little as 5–6 days in peak conditions [17].

### **4. Organic Matter Accumulation**

Leaf litter, soil particles, and microbial films accumulate in abandoned containers. These serve as rich food sources for larvae, promoting high survivorship and faster development [24].

### **5. Egg-Banking and Hatching Trigger**

Adult females lay eggs on container walls above the waterline. These eggs remain viable for months, allowing populations to

spike quickly when water levels rise even after long dry spells [16].

Together, these mechanisms create high-density larval hotspots that continually replenish adult mosquito populations.

## **Studies on *Aedes aegypti* Larval Density in Relation to Abandoned Containers**

A substantial body of research from different tropical and subtropical regions confirms that abandoned containers are the most productive breeding sites for *Aedes aegypti*. This section summarizes key empirical studies from Africa, Asia, and the Americas, drawing out patterns, differences, and emerging insights. Emphasis is placed on recent findings from 2015–2024 to ensure relevance.

### **Evidence from Africa**

African cities face rising dengue incidence due to rapid urbanization, inadequate waste disposal, and widespread container accumulation.

#### **Nigeria**

Olawale and Oduola [23] conducted a comprehensive survey in southwestern Nigeria and found that residential areas with poor waste management had significantly higher larval densities than cleaner communities. Discarded plastic containers and tires accounted for over 60% of all positive breeding sites.

In northern Nigeria, Eneh *et al.* [2] reported similar results, noting that peri-urban settlements with informal dumping sites exhibited threefold increases in larval density compared to organized residential zones.

#### **Kenya**

Ngugi *et al.* [24] observed that households that accumulated unused water storage

buckets, drums, and plastic containers had markedly higher *A. aegypti* infestation. Their analysis highlighted that abandoned plastic containers were the strongest predictor of larval presence.

### **Ghana and Tanzania**

Boateng *et al.* [27] identified that approximately 70% of all *Aedes* larvae in urban Ghana were found in household containers especially unwashed buckets and old paint tins. Meanwhile, Mboera *et al.* [28] in Tanzania highlighted that water stored in abandoned containers around construction sites contributed significantly to dengue outbreaks in Dar es Salaam.

### **Evidence from Asia**

Asia continues to report some of the highest global dengue cases, and container-breeding behaviour is recognized as a primary cause.

### **India**

Regmi *et al.* [21] analyzed larval ecology across three Indian states and found that areas with poor waste handling practices showed a 45–60% rise in larval density. The most productive containers were discarded tires, coconut shells, and plastic water containers.

### **Malaysia and Indonesia**

Rahim *et al.* [26] reported that the Breteau and House Indices in Malaysian urban areas were directly proportional to the density of abandoned small containers. Light-coloured plastic containers and flower pot trays were highly productive during the rainy season.

In Indonesia, Siregar *et al.* [29] demonstrated that improper disposal of household plastics increased larval

density by creating long-lasting breeding sites, especially during monsoon seasons.

### **Sri Lanka**

A study by Gunathilaka *et al.* [30] revealed that larval density was highest in containers with undisturbed water, such as unused cisterns, paint buckets, and roof gutters. The presence of these containers strongly correlated with dengue clusters.

### **Evidence from the Americas**

South America and the Caribbean have long been hotspots for *Aedes*-borne diseases, and container breeding remains central.

### **Brazil**

Fayomi *et al.* [25] found that over 80% of *Aedes aegypti* larvae were found in abandoned tires and disposable plastic containers. Their analysis further showed that container density was the strongest predictor of dengue hotspots at the community level.

### **Colombia**

Vega *et al.* [31] reported that abandoned household items particularly buckets, metallic tins, and water containers were the main larval habitats. Their findings emphasized that eliminating containers could reduce larval populations by up to 70%.

### **Mexico**

Vega *et al.* [31] found that schools and households with poor environmental sanitation had significantly higher container indices. Discarded school items such as old buckets, broken water fountains, and unused trays were surprisingly productive breeding sites.

### **Emerging Trends in Recent Studies (2019–2024)**

Recent research has identified new trends worth noting:

### 1. Microplastic Pollution and Mosquito Growth

A 2023 study by Suman et al. found that microplastics in water containers can accelerate larval development by altering water chemistry.

### 2. Construction Site Containers

Abandoned paint buckets, cement bags, and wheelbarrows at building sites emerged as major hotspots during the COVID-19 lockdown, when economic slowdown left many sites unattended [32].

### 3. Climate Change Effects

Rocklöv and Dubrow [19] showed that rising temperatures expand the seasonal window for larval development and increase productivity in containers that were previously marginal.

### 4. Waste Plastic Explosion

The rising global plastic waste crisis is creating more artificial habitats for *A. aegypti* than ever before [33].

### Public Health Significance of *Aedes aegypti* Larval Proliferation in Abandoned Containers

Understanding the density of *Aedes aegypti* larvae in abandoned containers is more than an entomological concern it is a major public health issue, especially for tropical and subtropical regions. The species is the primary vector of dengue, Zika, chikungunya, and yellow fever, and its breeding success directly influences the frequency and severity of outbreaks.

Recent global trends show that dengue incidence has increased tenfold over the last two decades, and researchers consistently link this rise to changes in

urban waste accumulation and human behaviour [34]. Abandoned containers whether scattered in homes, markets, or construction sites serve as “micro-incubators,” turning even a small amount of rainwater into a productive breeding habitat. This coupling of environmental neglect and mosquito ecology elevates community transmission risks.

In many communities, the availability of such containers correlates strongly with household-level dengue vulnerability. For example, a 2022 multi-city analysis in Brazil showed that areas with high density of discarded water-holding items reported significantly higher dengue attack rates, even after controlling for socioeconomic status [35]. Similar findings have been reported in Nigeria, Ghana, India, Malaysia, and the Philippines, reinforcing that poor container management is a universal driver of *Aedes* proliferation.

From a biological standpoint, a higher larval density in these containers translates into a robust adult mosquito population capable of sustaining intense human-mosquito contact. Since *Aedes aegypti* is highly anthropophilic preferring humans over other animals any increase in adult density increases the probability of virus transmission within a very short window of time [22]. Consequently, larval surveys in abandoned containers are often used as an early warning tool for predicting dengue outbreaks.

Overall, the public health significance lies in three core realities:

1. More containers = more larvae = more adult mosquitoes.
2. More adult mosquitoes = higher vectorial capacity and transmission potential.

3. Improper waste and container management = preventable outbreaks.

These relationships make abandoned container control a cost-effective and highly impactful public health strategy. Communities that improve waste disposal, container elimination, and sanitation practices often see dramatic reductions in dengue incidence [30].

### Future Directions and Way Forward

Addressing the challenges posed by *Aedes aegypti* proliferation in abandoned containers requires innovative research, community engagement, and sustainable policy implementation. Traditional top-down vector control programs have proven insufficient, highlighting the need for strategies that actively involve local communities in waste management and container elimination. Educational campaigns, regular clean-up initiatives, and incentivized waste disposal systems can empower residents to take ownership of their environment, while emerging technologies such as drone-assisted mapping, artificial intelligence, and predictive modeling could revolutionize the identification of container hotspots, enabling timely interventions.

Future research should also explore integrated biological and environmental approaches. The use of *Wolbachia*-infected mosquitoes, larvivorous predators, and environmentally safe larvicides, when combined with community-level container management, may provide a sustainable and ecologically friendly method of reducing larval densities. Urban planning policies that incorporate proper drainage, waste collection, and monitoring of construction sites are equally critical, ensuring that rapid urbanization does not

inadvertently create new breeding grounds. Climate change further complicates the picture, as rising temperatures extend the seasonal window for larval development and increase container productivity, necessitating adaptive strategies that anticipate shifting mosquito ecology.

Ultimately, an interdisciplinary approach that brings together entomologists, public health specialists, urban planners, sociologists, and behavioral scientists is essential. Understanding the interplay between human behavior, environmental management, and mosquito ecology will allow the design of interventions that are both effective and sustainable. By integrating technological innovation, community engagement, and evidence-based policy, it is possible to reduce larval density in abandoned containers, curb adult mosquito populations, and ultimately decrease the burden of *Aedes*-borne diseases.

### Conclusion

The proliferation of *Aedes aegypti* in abandoned and unwanted containers represents a persistent public-health challenge in tropical and subtropical regions. This review demonstrates that container characteristics, human behavior, urbanization, and climate collectively influence larval density and, consequently, disease transmission. Abandoned containers act as ecological amplifiers, sustaining mosquito populations even under suboptimal environmental conditions, while the species' behavioral and physiological adaptations, including egg resilience and skip oviposition, reinforce this persistence.

Evidence from Africa, Asia, and the Americas consistently highlights that container-rich environments are the most

productive breeding sites. Poor waste management, irregular sanitation, and rapid urbanization exacerbate the problem, creating densely populated mosquito habitats near human settlements. The ecological fit between *Aedes aegypti* and anthropogenic containers underscores that vector control cannot rely solely on chemical or biological interventions but must include community-driven environmental management. Future strategies should integrate innovative surveillance, sustainable waste management, urban planning, biological control, and climate-adaptive measures to mitigate vector proliferation. By addressing both the ecological and socio-behavioral drivers of larval density, it is possible to reduce the public-health impact of Aedes-borne diseases. Ultimately, the control of abandoned containers, alongside integrated interventions, represents a cost-effective and impactful approach to safeguarding human health in urban and peri-urban tropical environments.

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