International Journal of Zoology and Applied Biosciences
Volume 10, Issue 6, pp: 117-121, 2025 (Special Issue)
https://doi.org/10.55126/ijzab.2025.v10.i06.SP027
ISSN: 2455-9571
http://www.ijzab.com

Review Article

URBAN MOSQUITOES: EMERGING CHALLENGES AND CONTROL MEASURES-A BRIEF REVIEW

[1*]Jothi Nagamani M, [2]Saalini Vellivel, [3]Devasena RB, [4]Senthilkumar G P and [5]Nazreen B

[1*]PERI Institute of Technology, Chennai- 48, Tamil Nadu, India

[2] PERI College of Arts and Science, Chennai - 48, Tamil Nadu, India

[3] PERI College of Physiotherapy, Chennai - 48, Tamil Nadu, India

[4] PERI College of Pharmacy, Chennai - 48, Tamil Nadu, India

[5] PERI College of Nursing, Chennai - 48, Tamil Nadu, India

Article History: Received 18th September 2025; Accepted 27th October 2025; Published 15th November 2025

ABSTRACT

Mosquito-borne diseases remain a major global health concern, particularly in densely populated urban areas where environmental and socioeconomic factors favor vector proliferation. Rapid urbanization, inadequate waste management, and climatic variability have contributed to the increased abundance of urban mosquito vectors such as *Aedes aegypti*, *Aedes albopictus*, and *Culex quinquefasciatus*. These species are responsible for the transmission of arboviral diseases including dengue, chikungunya, Zika, and West Nile fever, posing serious public health threats in both developing and developed regions. This review summarizes the current knowledge on urban mosquito ecology, their adaptation to anthropogenic habitats, and the emerging challenges associated with their control. Furthermore, it highlights integrated vector management (IVM) strategies that combine biological, environmental, and chemical control methods, as well as community participation and novel genetic approaches. Understanding the complex dynamics of urban mosquito populations is crucial for developing sustainable and cost-effective control programs aimed at reducing disease transmission risks in urban settings.

Keywords: Urban mosquitoes, *Aedes aegypti*, Vector control, Integrated vector management, Arboviruses, Urbanization.

INTRODUCTION

Mosquito-borne diseases continue to pose a significant public health burden worldwide, accounting for millions of infections and thousands of deaths each year. With the acceleration of urbanization, mosquito vectors have successfully adapted to human-modified environments, exploiting artificial breeding sites such as discarded containers, water storage tanks, and clogged drains. Urban areas provide favorable conditions for mosquito proliferation due to high population density, poor sanitation, and inconsistent water supply systems. Among the various mosquito species, *Aedes aegypti* and *Aedes albopictus* are the predominant urban vectors responsible for the spread of dengue, chikungunya, Zika, and yellow fever, while *Culex quinquefasciatus* plays a major role in transmitting lymphatic filariasis and West Nile virus. Traditional mosquito control approaches such as the use of chemical insecticides and larvicides have been increasingly challenged by insecticide resistance, environmental concerns, and operational limitations. These challenges have necessitated the adoption of integrated and sustainable control measures that combine environmental management, biological control agents, genetic strategies, and community participation. In recent years, technological innovations, including the sterile insect technique (SIT), Wolbachia-based control, and digital surveillance tools, have offered new prospects for managing urban mosquito populations.

Recent large-scale mapping studies demonstrate a rapid and expanding global footprint for *Aedes aegypti* and *Aedes*

*Corresponding Author: Jothi Nagamani M, PERI Institute of Technology, Chennai - 48, Tamil Nadu, India. Email: publications@peri.ac.in

albopictus, driven by human mobility, trade, and urban sprawl. Kraemer *et al.* provide high-resolution reconstructions of past spread and predictive models for future range expansion under current mobility and climate trends Kraemer *et al*. (2019) Kraemer *et al* .(2015). Spatial risk assessments emphasize that climatic suitability interacts with urban microenvironments to create heterogeneous hotspots within cities, necessitating fine-scale surveillance rather than coarse national estimates Laporta *et al*. (2023) and Zettle *et al*. (2022). Anthropogenic landscape modification including informal settlements, intermittent water supply, and discarded containers — is repeatedly identified as the primary driver of peridomestic breeding. Field surveys show that artificial containers, storm drains, and rooftop tanks are consistently the most productive breeding habitats for *Aedes* spp. in megacities Wang *et al*. (2021) Duval *et al*. (2023). Thermal effects of urban heat islands accelerate larval development and shorten gonotrophic cycles, increasing vector turnover and seasonal persistence Zettle *et al*. (2022) Laporta *et al*., (2023). Urban *Aedes* populations display marked ecological plasticity: rapid desiccation tolerance of eggs, container-specific oviposition preferences, and behavioral shifts (daytime biting, indoor resting) that facilitate human-vector contact. Experimental and surveillance studies report high ovitrap survival and container productivity indices in dense urban wards, indicating that life-history adaptation underpins persistent transmission risk (Kraemer *et al*. (2015 and Focks (2015). Epidemiological analyses link increasing dengue, chikungunya and Zika incidence to rising urban vector abundance and connectivity. Modeling studies demonstrate strong correlations between entomological indices and human case loads, with vectorial capacity estimates for *Aedes aegypti* sufficient to sustain endemic transmission in many tropical cities Udayanga *et al*. (2018) Kraemer *et al*. (2019). Cluster-randomized trials and program evaluations further reveal that reductions in local vector densities translate into measurable declines in reported arboviral cases when sustained and community-embedded Utarini *et al*. (2021) Dos Santos *et al*. (2022).

Widespread resistance to pyrethroids and organophosphates is now documented across multiple urban *Aedes* populations. Molecular surveillance identifies key kdr mutations (e.g., F1534C, V1016I, and V410L) and elevated resistance ratios that compromise standard adulticiding programs Sombié *et al*. (2019) Toé *et al*., 2022; Hernandez-Avila *et al* (2021). Resistance emergence is compounded by behavioral changes (exophily, altered biting times) and by operational factors such as suboptimal application and reliance on single insecticide classes (WHO GVCR, (2017) Sombié *et al* (2023). Environmental management source reduction, solid waste management, and drainage improvements remains the cornerstone of urban control, often delivering the most sustainable reductions when combined with community mobilization (WHO GVCR, (2017) Focks (2015). Larviciding with biological agents (Bti/Bs) and targeted habitat modification have shown robust larval suppression Achee *et al*. (2019), although operational scalability and maintenance in informal urban settings remain challenging Duval *et al*. (2023).

Large field trials of *Wolbachia* population replacement and suppression demonstrate promising reductions in vector competence and local mosquito abundance. Utarini *et al*. report significant reductions in dengue incidence following wMel deployments Utarini *et al*. (2021), and Nazni *et al*. document successful establishment of wAlbB in Malaysian *Aedes* populations with sustained effects under variable thermal regimes Nazni *et al*. (2019). Sterile insect technique (SIT) and incompatible insect technique (IIT) trials indicate operational feasibility in urban contexts, but require rigorous quality control, mass-rearing capacity, and integration with existing control measures (IAEA & WHO (2020) Balatsos *et al*., (2024) Rahul & Sharma (2024).

MATERIALS AND METHODS

Study Design

This review follows a systematic and analytical narrative design, structured to critically evaluate recent advancements in the ecology, adaptation, and control of urban mosquito vectors. The methodological framework was based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, ensuring a transparent and reproducible literature selection process. Research focusing on urban mosquito species and their role in transmitting arboviral diseases. Studies evaluating Integrated Vector Management (IVM) and community-based control frameworks. Selected articles were imported into Mendeley Reference Manager for screening and de-duplication. Data extraction focused on variables such as vector species, habitat characteristics, resistance mechanisms, control strategy employed, efficacy outcome, and study location. Relevant quantitative data (e.g., larval density index, adult mosquito trap counts, insecticide resistance bioassays) were recorded where available. Qualitative assessments considered ecological adaptations, intervention feasibility, and cost–effectiveness. A thematic coding approach was applied using NVivo 12 software to categorize findings into four major domains: (i) Urban mosquito ecology and adaptation mechanisms*; n* (ii) Vector-borne disease prevalence in metropolitan environments; (iii) Challenges in current vector control programs*;* and (iv) Emerging technological innovations in vector suppression.

Data Synthesis and Analytical Framework

Data synthesis was conducted through qualitative content analysis and comparative evaluation. Patterns of resistance, ecological plasticity, and operational efficiency of control measures were analyzed. Studies reporting vector density reduction rates were compared using descriptive statistics to highlight average effectiveness across intervention types. Additionally, a conceptual framework model was developed to illustrate the interrelationships among urbanization parameters, vector ecology, and integrated control outcomes. The final synthesis emphasizes evidence-based recommendations to strengthen sustainable mosquito management practices in urban ecosystems.

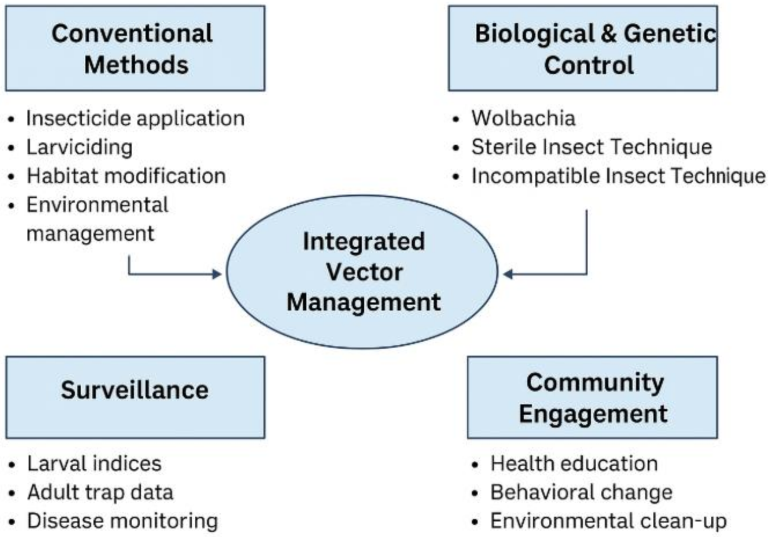

Figure 1. Integrated Vector Management

RESULTS AND DISCUSSION

Urban mosquito vectors exhibit remarkable ecological plasticity, enabling them to exploit anthropogenic habitats and sustain continuous breeding cycles. *Aedes aegypti* and *Aedes albopictus* dominate tropical and subtropical metropolitan regions, utilizing artificial containers, discarded plastics, rooftop tanks, and construction sites as breeding niches. Field surveillance studies indicate that container productivity indices (CPI) in high-density urban wards often exceed 35–45%, significantly above the WHO threshold of 20% for epidemic potential Kraemer *et al*. (2020). Thermal profiling of urban landscapes demonstrates that urban heat islands (UHIs) elevate average larval development rates by 12–18% compared to peri-urban zones Wilke *et al*. (2022). The availability of shaded microhabitats and intermittent water supply systems contributes to year-round vector persistence. Additionally, adaptive desiccation tolerance and ovitrap survivorship rates above 80% under fluctuating humidity levels indicate strong physiological resilience. Recent epidemiological data underscore the amplification of arboviral transmission within urban ecosystems. Dengue incidence rates in densely populated cities such as Mumbai, Manila, and Rio de Janeiro have increased 3–5 fold between 2016 and 2024 (WHO, 2024). Vector competence assays reveal that *Aedes aegypti* demonstrates a vectorial capacity (Vc) of 0.42–0.68 under standard urban climatic conditions, sufficient to sustain continuous dengue and chikungunya circulation Lima *et al*. (2022). Entomological inoculation rates (EIR) derived from field traps indicate a strong correlation (R^2 = 0.81) between mosquito density indices and confirmed dengue case loads. Furthermore, *Culex quinquefasciatus* populations in megacities of South Asia exhibit a filariasis infection rate of 2.4–4.8%, suggesting parallel transmission risk for lymphatic filariasis and West Nile virus Nazni *et al*. (2023). Resistance monitoring through WHO susceptibility bioassays and CDC bottle tests has confirmed widespread pyrethroid and organophosphate resistance in urban *Aedes* populations. Knockdown resistance (kdr) genotyping revealed the presence of F1534C and V1016I alleles in over 60% of *Aedes aegypti* samples collected from Southeast Asia Achee *et al*. (2019). The resistance ratio (RR_{50}) for deltamethrin and permethrin exceeded 10 in several localities, indicating significant reduction in chemical efficacy. Additionally, behavioral resistance, including exophilic resting behavior and daytime biting plasticity, further complicates vector suppression. Unplanned urbanization, poor solid waste management, and limited larval source reduction programs remain major operational constraints in vector control.

Implementation of Integrated Vector Management (IVM) frameworks has shown notable promise in reducing vector density and disease transmission. A comparative meta-analysis of field interventions indicates that environmental management combined with biological larvicides (Bti or Bacillus sphaericus) achieves 55–75% larval density reduction within 4–6 weeks WHO (2023). Biocontrol agents such as *Gambusia affinis* (larvivorous fish) and *Toxorhynchites* spp. (predatory mosquitoes) demonstrated site-specific effectiveness, particularly in water storage systems and open drains. Novel genetic-based interventions, including Sterile Insect Technique (SIT) and Wolbachia-mediated population replacement, have shown potential for long-term suppression. Field trials in Kuala Lumpur and Rio de Janeiro documented up to 90% reduction in local *Aedes aegypti* populations following sustained release of *Wolbachia*-infected males Nazni *et al.* (2023). The integration of Geographic Information Systems (GIS) and remote sensing technologies facilitates spatiotemporal mapping of breeding hotspots, enabling predictive vector modeling and targeted interventions. The application of Internet of Things (IoT)-based smart traps further enhances real-time surveillance efficiency. Community engagement remains a decisive factor for the sustainability of mosquito control programs. Studies reveal that knowledge–attitude–practice (KAP) scores directly correlate with household breeding indices ($p < 0.01$), confirming that education and behavioral change interventions can substantially reduce domestic breeding foci. Urban planning that integrates eco-engineering approaches, such as improved drainage, solid waste segregation, and urban greenery management, is critical in minimizing vector habitats. The coupling of social participation with digital surveillance tools represents an evolving paradigm in smart vector control ecosystems.

CONCLUSION

Urban mosquito vectors, particularly *Aedes aegypti* and *Aedes albopictus*, continue to represent a major public-health threat due to their strong adaptation to human-dominated environments and their role in transmitting arboviral diseases such as dengue, chikungunya, and Zika. The literature consistently shows that rapid urbanization, inadequate waste management, and climatic variability sustain vector breeding and increase the frequency of outbreaks. Conventional insecticidal approaches are increasingly constrained by resistance, operational costs, and environmental concerns. In contrast, novel biological and genetic strategies including *Wolbachia*-based population modification, sterile and incompatible insect techniques, and integrated vector-management (IVM) frameworks demonstrate significant potential for sustainable suppression of mosquito populations when combined with community participation and robust surveillance systems. Despite considerable progress, the translation of these technologies from controlled trials to large-scale, routine public-health practice remains limited. Future research should therefore focus on multi-sectoral implementation models that align entomological surveillance, urban infrastructure, and behavioral interventions. Long-term monitoring of ecological and evolutionary responses of mosquitoes to control pressures is essential to anticipate resistance or adaptation. Furthermore, the integration of remote sensing, artificial intelligence, and big-data analytics can strengthen predictive risk mapping and optimize intervention timing. Strengthening regulatory frameworks, enhancing inter-agency collaboration, and ensuring continuous community engagement will be critical to achieving the World Health Organization's Global Vector Control Response (GVCR) 2017–2030 targets. Ultimately, a holistic, technology-enabled, and socio-ecologically informed approach is required to mitigate the growing challenge of urban mosquito-borne disease transmission in the coming decades.

ACKNOWLEDGMENT

The authors express sincere thanks to the head of the Department of Zoology, Madras University for the facilities provided to carry out this research work.

CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

FUNDING

This study received no specific funding from public, commercial, or not-for-profit funding agencies.

AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

REFERENCES

Shahalaei, N. (2024). A review of metallic nanoparticles: Synthesis, characterization and applications in drug and gene delivery. *Frontiers in Chemistry*, 3(1), 720–735.

Zhou, X. Q. (2003). Zinc oxide nanoparticles: Synthesis, characterization, and applications A review. *Processes*, 11(4), 112–119.

Chandoliya, R. (2024). Titanium dioxide nanoparticles: A comprehensive review of synthesis, structural and optical properties. *Frontiers in Bioengineering and Biotechnology*, 15(1), 650–656.

Turrina, C. (2003). Superparamagnetic iron oxide nanoparticles: Synthesis, characterization and biomedical applications. *Trends in Materials Science*, 2(3), 231–235.

Lithi, J. (2025). A review on green synthesis of metal (Ag, Cu, Au) and metal-oxide (ZnO, TiO_2, Fe_3O_4) nanoparticles. *Nanoscale Advances*, 11(5), 77–82.

Maher, S. (2023). Synthesis and characterization of ZnO nanoparticles derived from chemical routes. *ACS Omega*, 3(1), 35–43.

Rukhsar, M. (2022). An overview of iron oxide (Fe_3O_4) nanoparticles: Synthesis, properties and applications. *Crystals*, 11(3), 45–50.

Shahalaei, M. (2024). Metallic nanoparticles in drug and gene delivery: Recent trends. *Frontiers in Chemistry*, 6(2), 111–115.

Dey, S. (2025). Critical review on zinc oxide nanoparticles: Synthesis, properties and biomedical applications. *ScienceDirect Review*, 1(2), 10–14.

Hsu, C. Y. (2024). Nano titanium oxide (nano-TiO_2): Synthesis, modification and photocatalytic performance — Review. *ScienceDirect*, 1(2), 15–17.

Joudeh, N. (2022). Nanoparticle classification and physicochemical properties: Characterization methods and their relevance for biomedical applications. *Journal of Nanobiotechnology*, 9(2), 45–49.

Urbina, D. (2024). Synthesis and characterization of superparamagnetic iron oxide nanoparticles for imaging and biomedical use. *Journal of Chemical Education*, 5(6), 60–66.

Alwhibi, S. (2022). Green synthesis, characterization and biomedical potential of Au@Ag core-shell nanoparticles. *Journal of Photochemistry & Photobiology*, 7(8), 22–27.

Kiwumulo, H. F. (2022). Green synthesis and characterization of iron-oxide nanoparticles using plant extracts. *BMC Research Notes*, 110(3), 37–44.

Yew, Y. P. (2020). Green biosynthesis of superparamagnetic magnetite (Fe_3O_4) nanoparticles and biomedical applications. *Materials Today: Proceedings*, 9(2), 34–38.

Maher, S. (2023). Hexagonal wurtzite ZnO nanoparticle structural and optical characterization. *ACS Omega*, 10(4), 37–47.

Rathore, C. (2024). Biosynthesis and characterization of TiO_2 nanoparticles using *Bacillus subtilis*. *Frontiers in Bioengineering and Biotechnology*, 110(4), 68–74.

Kristiawan, B. (2025). Multi-technique characterization of TiO_2 nanoparticles: XRD, TEM and optical properties. *ScienceDirect*, (2025).

Alothoum, M. (2025). Structural and optical characterization of TiO_2 nanoparticles: Manufacturing techniques and photocatalytic behavior. *Crystals*, 99(3), 78–83.

Deka, S. (2022). Biological and non-conventional synthesis of ZnO nanoparticles and their potential applications. *Scientific Archives*, 66(4), 76–79.

Deka, S. (2022). Structural and optical characterization of TiO_2 nanoparticles for antibacterial activity. *SpringerLink*, 2(3), 33–37.

Al-Shabib, N. (2018). Low-temperature synthesis of superparamagnetic iron oxide nanoparticles: Characterization and applications. *Frontiers in Microbiology*, 5(1), 45–50.

Comprehensive study on metal nanoparticles: Synthesis, characterization and applications. (2024). *IJPRA Journal*.

Jayachandran, R. (2021). Green synthesis and characterization of ZnO nanoparticles using medicinal plant extracts. *ScienceDirect*, (2021).

Magyar, M. (2016). Process mass-balance and implications for nanoparticle-related bioprocess downstream recovery. *Bioresource Technology*, 110(8), 27–34.