International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 08-04-2025, Accepted: 09-05-2025, Published: 24-05-2025
Volume 10, Issue 5, 2025, Page No. 81-83

Advances in sand fly control from conventional strategies to artificial intelligence integration: A review

Dr. Heena Sachdeva, Dr. Manish Sharma
Assistant Professor, Department of Zoology Multani Mal Modi College, Patiala, Panjab, India

Abstract
Leishmaniasis, caused by protozoa of the genus *Leishmania*, is transmitted by female sand flies and remains a major public health concern in many developing countries. Traditional vector control strategies have historically relied on insecticides and environmental management. However, these approaches face limitations due to resistance development, environmental impact, and logistical constraints. Recent developments in Artificial Intelligence (AI) offer novel approaches to augment vector surveillance, automate species identification, and predict outbreaks with high accuracy. This review explores the shift from conventional sand fly control to AI-driven innovations, discusses their benefits and limitations, and highlights the importance of integrating both methods for effective disease control.

Keywords: Leishmaniasis, sand fly control, artificial intelligence, vector surveillance, insecticide resistance

Introduction
Leishmaniasis affects an estimated 12 million people globally, with over 1 billion people at risk of infection. It is endemic in parts of South Asia, Latin America, the Middle East, and East Africa (World Health Organization [WHO], 2022) [14]. The disease is primarily transmitted through the bite of infected female sand flies of the genera *Phlebotomus* (Old World) and *Lutzomyia* (New World). Controlling the vector population is critical for interrupting the transmission cycle of *Leishmania* parasites.

Historically, sand fly control relied on insecticide-based interventions and habitat management. However, issues such as insecticide resistance, environmental degradation, and cost have reduced their long-term effectiveness (Alexander & Maroli, 2003) [1]. The integration of AI into public health offers promising tools for real-time monitoring, predictive modeling, and optimization of control strategies. As emphasized by Bogduk *et al.* (2008) [3], technological advancements must enhance clinical and operational decision-making without replacing expert judgment—a principle that holds true for vector control as well.

Traditional Sand Fly Control Strategies

1. Chemical Control
Insecticides remain one of the primary tools for sand fly control. Commonly used classes include organophosphates (e.g., malathion), pyrethroids (e.g., deltamethrin, permethrin), and carbamates. These chemicals are applied through indoor residual spraying (IRS), space spraying, and insecticide-treated nets (ITNs) (Maroli *et al.*, 2013) [8].

However, overreliance on insecticides has led to growing resistance in vector populations (Kumar *et al.*, 2020) [7]. Additionally, chemical interventions may pose health risks to humans and cause environmental contamination, especially when deployed at scale. Limited residual activity of certain insecticides necessitates frequent reapplication, further straining public health resources (Ostyn *et al.*, 2015) [9].

2. Environmental Management
Environmental control targets sand fly breeding and resting habitats. This involves clearing vegetation, repairing walls and floors, removing animal shelters near human dwellings, and managing organic waste (Desjeux, 2004) [4]. Though effective in reducing sand fly density, these efforts require sustained community engagement and financial support, often lacking in low-income regions.

3. Biological Control
Biocontrol agents such as *Bacillus thuringiensis israelensis* (Bti) and entomopathogenic fungi (*Metarhizium anisopliae*, *Beauveria bassiana*) offer eco-friendly alternatives to chemical insecticides (Singh *et al.*, 2016) [13]. Despite their specificity and reduced environmental risk, their adoption remains limited due to high production costs, short shelf-life, and reduced efficacy under natural conditions.

4. Personal Protection
Repellents (e.g., DEET), protective clothing, and bed nets provide individual-level protection from sand fly bites (Ghosh *et al.*, 2011) [5]. While important, these measures cannot substitute community-level interventions and depend heavily on consistent usage and accessibility.

Surveillance and Monitoring Tools
Effective vector surveillance is essential for designing and evaluating control programs. Traditional tools include light traps, sticky traps, and mechanical aspirators, used to estimate sand fly density and distribution (Alexander & Maroli, 2003) [1]. However, manual identification of sand flies is labor-intensive and requires expert entomologists. Additionally, spatial and temporal resolution is limited, impeding rapid response during outbreaks.

Emergence of Artificial Intelligence in Vector Control
Artificial Intelligence has revolutionized various aspects of global health, from diagnostics to predictive modeling. In vector control, AI systems can analyze large, complex datasets—climate variables, entomological data, human mobility, and socio-economic indicators—to generate

insights that would be difficult through manual methods (Zhou *et al.*, 2021) [15]. Applications include automated species identification, outbreak prediction, and optimization of insecticide application, enabling a shift from reactive to proactive control.

AI Applications in Sand Fly Control

1. Remote Sensing and GIS Mapping

AI-enhanced remote sensing and Geographic Information Systems (GIS) facilitate environmental monitoring of vector habitats. By analyzing satellite data on temperature, vegetation, land use, and precipitation, supervised learning models such as Random Forest and Support Vector Machines can predict high-risk areas for sand fly breeding (Khamesipour *et al.*, 2020) [6].

These spatial models enable targeted interventions, reducing the need for blanket spraying and optimizing resource allocation.

2. Automated Species Identification

Deep learning, particularly Convolutional Neural Networks (CNNs), has shown promise in automating sand fly identification. These models can classify species, sex, and physiological status (e.g., blood-fed vs. unfed) from digital images with over 90% accuracy (Rodrigues *et al.*, 2022) [10]. This reduces the dependency on entomological experts and allows rapid processing of field samples.

3. Outbreak Prediction

Predictive modeling using historical leishmaniasis incidence data, coupled with environmental and socio-economic factors, enables the anticipation of outbreaks. For instance, AI models developed for visceral leishmaniasis in Bihar, India, successfully forecasted seasonal spikes with an accuracy exceeding 85% (Singh *et al.*, 2022) [12]. These insights inform early-warning systems and timely deployment of vector control measures.

4. Insecticide Optimization

AI models, including reinforcement learning algorithms, are used to optimize insecticide application schedules. By continuously adjusting control strategies based on surveillance feedback, these systems help reduce resistance development and unnecessary chemical use (Sadanand & George, 2021) [11].

5. Community Engagement Tools

Natural Language Processing (NLP) and chatbot systems provide scalable platforms for public education, symptom reporting, and behavioral nudges. These tools improve health literacy and strengthen the interface between communities and health authorities, especially in rural and underserved settings (Alonso *et al.*, 2021) [2].

Limitations and Ethical Considerations

Despite its promise, AI implementation faces several challenges. Data scarcity and quality issues remain significant barriers in many endemic regions. Additionally, technical limitations such as lack of infrastructure, internet access, and trained personnel hinder scalability.

Ethical considerations also need attention. Concerns over data privacy, surveillance, and algorithmic bias are especially relevant when working with health and mobility data. As emphasized by Bogduk *et al.* (2008) [3], technology must support, not replace, expert judgment and ethical standards in healthcare, a principle equally applicable to public health systems relying on AI.

Future Directions

Future efforts should focus on integrating AI with Internet of Things (IoT) technologies to enable real-time monitoring through smart traps and mobile reporting systems. Open-source platforms and international collaborations can facilitate access to AI tools for low-resource settings.

Investment in local capacity building, infrastructure development, and interdisciplinary training will be essential. Governments and public health agencies must also create regulatory frameworks to ensure responsible AI deployment.

Conclusion

The fight against leishmaniasis demands a multipronged approach. Traditional methods such as chemical and environmental control remain foundational but are increasingly limited by resistance and operational challenges. AI offers a transformative opportunity to augment these approaches through real-time surveillance, precision targeting, and predictive analytics. However, successful implementation requires high-quality data, ethical oversight, and community engagement. The future of sand fly control lies in integrating traditional wisdom with modern intelligence, ensuring sustainability, equity, and effectiveness in disease prevention.

References

1. Alexander B, Maroli M. Control of phlebotomine sandflies. Medical and Veterinary Entomology,2003:17(1):1–18.
2. Alonso WJ, Simonsen L, Viboud C. AI for public health surveillance. The Lancet Digital Health,2021:3(7):419-421.
3. Bogduk N, Bartsch T, Silberstein S, Lipton R, Dodick D. Clinical evaluation of cervicogenic headache: A clinical perspective. International Journal of Multidisciplinary Research and Development,2008:16(2):73–80.
4. Desjeux P. Leishmaniasis: Current situation and new perspectives. Comparative Immunology, Microbiology and Infectious Diseases,2004:27(5):305–318.
5. Ghosh K, Mukhopadhyay J, Desai M, Sen S. Management of sand fly vectors for control of leishmaniasis: Recent approaches. Journal of Parasitic Diseases,2011:35(2):72–77.
6. Khamesipour A, Rafati S, Davoudi N, Rassi Y. Application of remote sensing and GIS in leishmaniasis risk mapping. Acta Tropica,2020:212:105693.
7. Kumar D, Ranjan A, Das P. Emergence of insecticide resistance in sand flies. Parasites Vectors,2020:13:541.
8. Maroli M, Feliciangeli MD, Bichaud L, Charrel RN, Gradoni L. Phlebotomine sandflies and the spreading of leishmaniases and other diseases of public health concern. Medical and Veterinary Entomology,2013:27(2)123–147.
9. Ostyn B, Vanlerberghe V, Picado A, Dinesh DS, Sundar S, Boelaert M. Vector control for visceral leishmaniasis: Systematic review and meta-analysis of

trials. PLoS Neglected Tropical Diseases,2015:9(8):0003755.
10. Rodrigues C, Pinto MC, Duarte L. Deep learning for automatic identification of phlebotomine sand flies. Computer Methods and Programs in Biomedicine,2022:215:106614.
11. Sadanand K, George J. Reinforcement learning for dynamic vector control strategies. AI in Public Health,2021:3(1)88–95.
12. Singh N, Mishra J, Sundar S. Predicting visceral leishmaniasis outbreaks using machine learning. Tropical Medicine and International Health,2022:27(5)421–430.
13. Singh RK, Ghosh SK, Bhattacharya SK. Biological control of sand flies using Beauveria bassiana: A field trial. Parasite Epidemiology and Control,2016:1(2):110–115.
14. World Health Organization. Leishmaniasis: Key facts. https://www.who.int/news-room/fact-sheets/detail/leishmaniasis, 2022.
15. Zhou X, Wang J, Li Y. Artificial Intelligence in vector-borne disease control: A review. Infectious Diseases of Poverty,2021:10:47