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VECTOR CONTROL STRATEGIES FOR TROPICAL PARASITIC DISEASES

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Absract

Tropical parasitic diseases, such as malaria, dengue fever, chikungunya, lymphatic filariasis, schistosomiasis, and leishmaniasis, are a significant global health issue, particularly in tropical and subtropical countries.but these diseases disproportionately affect vulnerable populations, such as the poor, rural, or marginalized, who lack access to healthcare, clean water, and sanitation. Despite decades of research and control activities, tropical parasitic diseases persist, highlighting the need for sustainable and effective solutions. Vector control has been a vital component of the global fight against these diseases, targeting the vectors of transmission to decrease infection prevalence. However, traditional tools like insecticides, indoor residual spraying, and environmental management have been progressively undermined by obstacles like insecticide resistance, vector behavioral changes, environmental determinants, and logistical hurdles.

New strategies, such as genetically modified mosquitoes, Wolbachia-infected mosquitoes, and spatial repellents, have offered new options for disease management. Integrated vector management (IVM) approaches have become increasingly recognized as a more sustainable and comprehensive means of vector control. This study discusses the changing face of traditional and new vector control methods for tropical parasitic diseases, assessing their effectiveness, scalability, and sustainability. The ultimate aim is to decrease the burden of tropical parasitic infections, achieve better health outcomes, and progress towards global health milestones.

Keywords: Vector, Control, Strategies, Tropical, Parasitic Diseases

Introdoction

Tropical parasitic infections, such as malaria, dengue, Zika, and Lyme disease, cause significant morbidity and mortality worldwide. Parasitic protozoan diseases continue to pose severe public health threats,and most has zoonatic origin (**Omowaye** *et al.,* 2019) but progress has been made in disease control and treatment yet,these infections, which are transmitted by mosquitoes, result in hundreds of thousands of fatalities annually, with the majority being children aged below five in sub-Saharan Africa. Dengue fever, spread by aedes mosquitoes, has also increased in incidence over the last few decades, causing severe manifestations such as dengue hemorrhagic fever. Lymphatic filariasis and schistosomiasis cause chronic disability and aesthetic deformities, leading to long-term suffering and reduced quality of life. Chagas disease, transmitted by triatomine bugs, can lead to severe cardiac and gastrointestinal complications. These infections also have economic and social consequences, with affected people, their families, and healthcare systems bearing a significant financial burden. Indirect costs result from lost production brought on by disease, disability, or early death, while direct costs include those associated with diagnosis, treatment, and hospitalization. In endemic areas, malaria is thought to cost billions of dollars a year in lost economic production and medical expenses.Braund KG, (2003).

Poverty is a result of and a cause of tropical parasite infections, as they flourish in environments where transmission is facilitated by inadequate sanitation, poor infrastructure, and restricted access to medical care. The high prevalence of chronic illnesses hinders economic growth by lowering worker productivity, raising healthcare expenses, and taking funds away from other vital sectors like infrastructure and education.More recently, genetic methods have drawn interest because to their potential to permanently reduce vector populations. Examples of these methods include the use of gene drives and the release of sterile insects (Devos *et al.*, 2022).

Global health equity is an issue, with high-income nations being mainly immune to these diseases, while low- and middle-income nations are disproportionately affected. Balancing effective vector control with environmental sustainability is a complex task that requires careful consideration of ecological impacts.(Bonfante-Cabarcas *et al.*,20211)

Increasing Chemical Use

As vectors expand, there might be a greater need for chemical control measures, which would worsen the state of the environment (Lawler, 2017).

- IVM, or integrated vector management: IVM encourages the application of several eco-friendly tactics, including habitat management, biological control, and community education. IVM implementation, however, can be resource-intensive and necessitates close stakeholder cooperation (Wong *et al.,* 2023).(Bryan*et al.,*2016)
- Natural Biopesticides and Repellents: Although biopesticides and natural repellents (such Bacillus thuringiensis or neem oil) are less damaging to the environment, they might be less efficient or more costly than chemical equivalents (Kumar *et al.,* 2021).

Behavioural Issues and Community Involvement

- Public Opposition: Because of inconvenience or ignorance, communities may oppose ecologically friendly vector control techniques like utilising bed nets or eliminating standing water (Harris *et al.,* 2019).
- Overreliance on Chemicals: The adoption of sustainable practices may be impeded in some areas by a cultural predilection for chemical solutions (Sovacool *et al.,* 2024).

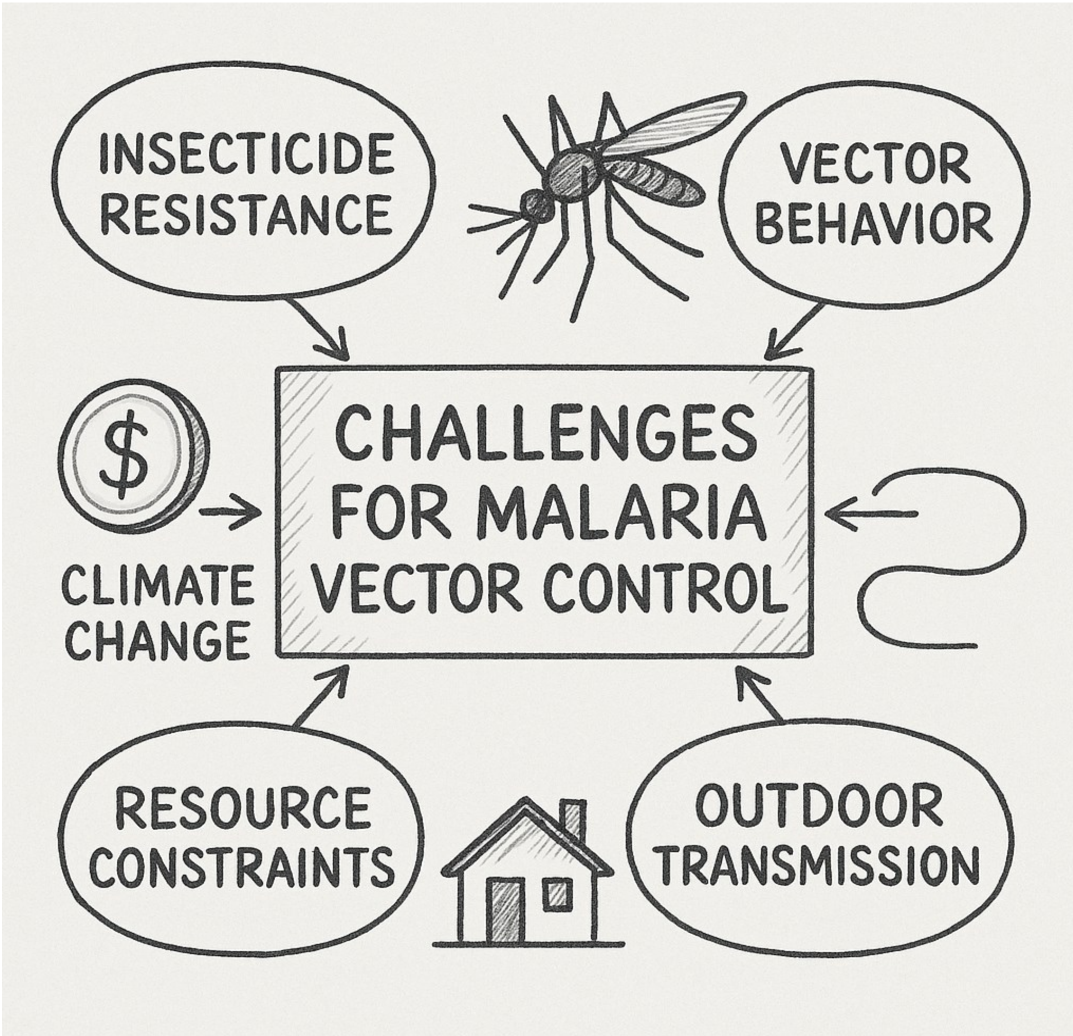

Figure 1: Pictorial diagram illustrating the challenges for malaria vector control
Source: omowaye *et al* (2025)

Importance of Tropical parasite and Vector control

Obame-Nkoghe *et al.* (2024) state that tropical parasite illnesses are a major public health concern, especially in low- and middle-income nations where ecological conditions encourage the spread of vectors.

Vector control is a crucial public health strategy aimed at reducing the spread of vector-borne diseases like malaria, dengue, Zika, and Lyme. However, it often faces significant economic challenges due to high implementation costs, restricted finance, and the complex economic dynamics of disease prevention. These challenges include increased implementation costs, limited government allocations, dependence on external financing, and economic recessions.

The cost-effectiveness of vector control interventions is also a challenge, as selecting the most economical algorithms can be costly and resistance can diminish returns over time. Vector-borne diseases also have significant economic impacts, such as healthcare expenses, productivity decline, and effects on tourism and trade.

Resource distribution disparities, urban-rural disparities, and marginalized populations can result in disparities in disease burden and access to interventions. Research and development expenses, such as the creation of new vector control instruments, can be costly and hinder innovation, especially for diseases primarily impacting low-income communities.

Vector control programs Sustainability

For vector control initiatives to be successful, behavioral factors—such as community acceptability and awareness—are essential (Kebede *et al.*, 2020).

Sustainability of vector control programs is also a concern, as long-term financial requirements and community engagement expenses can be challenging. Climate change and globalization are also causing more frequent and severe disease outbreaks, exacerbating economic burdens. Therefore, vector control must adapt to these economic challenges to ensure its effectiveness and sustainability.

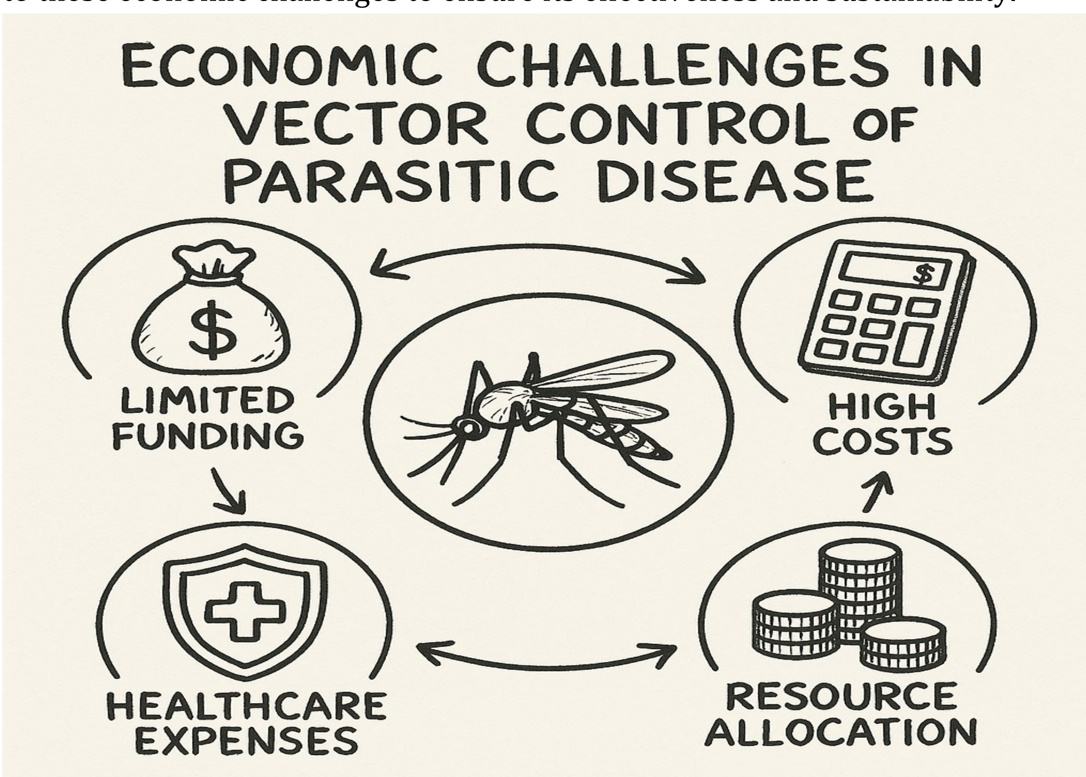

Figure 2: Economic Challenges in Vector Control, **Source:** omowaye *et al.,* (2025)

Vector control is a crucial aspect of public health initiatives aimed at addressing vector-borne diseases like malaria, dengue, Zika, and chikungunya. However, behavioural problems can significantly impede the implementation and longevity of vector control strategies. These challenges arise from cultural, social, and psychological aspects that shape individual and community perceptions and responses to vector control efforts.

Significant behavioral issues in vector control include lack of knowledge and awareness, limited health literacy, traditional beliefs, stigma and terror, resistance to behavior change, lack of faith in authorities, social and economic barriers, gender roles and responsibilities, perception of risk and complacency, skepticism towards innovations, lack of familiarity with new technologies, changes in lifestyle and urbanization, and difficulties in communication.

Lack of knowledge and awareness, traditional beliefs, stigma, and fear of repercussions can hinder the adoption of scientifically validated vector control techniques. Resistance to change may result from comfort with status quo, perceived inconvenience, and lack of faith in authorities.

Social and economic barriers, such as the cost of interventions and gender roles, can also hinder the acceptance of vector control programs. Additionally, people may underestimate their risk of infection and become complacent after successful vector control initiatives, leading to disease resurgences.

Vector control initiatives should adopt a comprehensive and community-focused approach to address behavioral issues. Key tactics include awareness and education campaigns, community engagement, behavioural nudges, resolving economic barriers, and leveraging local leaders. Vector-borne diseases are prevalent in tropical and subtropical areas, and are spread by infectious arthropods such as mosquitoes, ticks, sandflies, and sandflies.

Mosquitoes spread malaria, which is a major cause of disease and mortality in sub-Saharan Africa. Other common vectors include Aedes mosquitoes, which spread dengue, Zika, Chikungunya, and Yellow Fever. Ticks spread Lyme Disease, Babesiosis, and Babesiosis, causing fever, exhaustion, joint discomfort, and neurological problems. Sandflies transmit several parasitic diseases, primarily in tropical and subtropical regions.

Tsetse flies are the primary vectors for African trypanosomiasis, also known as sleeping sickness. Triatomine bugs are vectors for Chagas disease, causing acute symptoms but long-term complications. Blackflies are vectors for onchocerciasis, also known as river blindness, causing severe skin itching, nodules, and visual

impairment. Fleas are vectors for plague and murine typhus, leading to high mortality rates if untreated.
Lice are vectors for diseases such as epidemic typhus and trench fever, causing chronic illness. Aquatic snails are intermediate hosts for schistosomiasis, a parasitic disease affecting millions worldwide.

Surveillance using Vector control against parasitic diseases
Vector surveillance is revolutionizing disease control by utilizing remote sensing and Geographic Information Systems (GIS) technology to track vector habitats and anticipate disease outbreaks. These technologies offer high-resolution information on environmental variables affecting vector breeding and dispersal, enabling applications such as identifying mosquito breeding sites, mapping disease risk zones, and guiding targeted interventions. Artificial Intelligence (AI) and machine learning are increasingly analyzing large volumes of data from vector surveillance systems, enabling pattern recognition, disease transmission prediction, and control strategy optimization.
Geomic and Molecular Tools enable more accurate vector population identification and monitoring, with methods like next-generation sequencing and DNA barcoding revealing vector species, their capacity to spread infections, and resistance to pesticides. These tools can be used to track the spread of insecticide-resistant mosquito populations, identify genetic markers associated with pathogen transmission, and develop targeted genetic control strategies.
Smart Traps and Sensors improve vector surveillance effectiveness by automatically gathering and transmitting data on vector populations, eliminating the need for human surveillance. Citizen Science and Mobile Technologies empower communities to participate in vector surveillance, providing real-time data to public health authorities and raising awareness about vector-borne diseases and prevention measures. Wearable and Environmental Sensors monitor human-vector interactions and environmental conditions that influence vector behavior. Autonomous and Robotic Systems are becoming increasingly potent instruments for vector control and monitoring, with robots and drones being used for releasing sterile mosquitoes or spraying insecticides in difficult-to-reach areas.
Big data and digital platforms have revolutionized vector surveillance, enabling more thorough and real-time insights. These platforms compile information from various sources, such as weather stations, satellite photos, medical records, and

citizen reports. Applications include creating dynamic risk maps for vector-borne diseases, facilitating data sharing and collaboration among researchers, policymakers, and healthcare providers, and supporting decision-making for targeted interventions. The "Global Vector Hub" is a digital platform that provides access to vector surveillance data, tools, and resources for researchers and public health professionals.

However, challenges such as cost and accessibility, data privacy and security, integration with existing systems, and capacity building are essential for the full realization of these potential. Technology plays a crucial role in vector control, as it helps improve sustainability, precision, and efficiency. Geospatial technology and data analytics enable mapping and tracking vector habitats and disease outbreaks, while genomic and biotechnology tools enable new approaches to vector control. IoT-enabled devices like sensors and smart traps provide real-time vector population monitoring, reducing manual surveillance and labor-intensive manual surveillance. Mobile and digital health applications empower communities to participate in vector control initiatives, allowing users to submit vector-borne disease symptoms or breeding grounds for early identification and surveillance. Automation and robotics are increasingly used in vector control procedures, with autonomous drones and robotic machines reducing human exposure to dangerous chemicals and increasing the effectiveness of vector control efforts. Climate and environmental monitoring also plays a significant role in vector distribution and behavior, with technology essential for tracking environmental variables impacting vector populations.

Tropical parasitic diseases, such as leishmaniasis, dengue, malaria, and lymphatic filariasis, pose a significant threat to global health. Traditional methods like insecticide-treated nets and environmental management have proven effective in reducing disease spread. However, cutting-edge technologies like robotics, IoT-enabled devices, genome editing, and geospatial technologies are transforming vector monitoring and control. These advancements enable real-time surveillance, predictive modeling, and focused interventions. However, challenges such as high costs, limited infrastructure, and technical competence need to be addressed. Ethical issues, particularly those related to genetically modified organisms, must be considered. A multidisciplinary and cooperative strategy is needed to ensure sustainable and efficient vector control. This includes addressing behavioral and socioeconomic hurdles, encouraging community involvement, and fusing traditional approaches with cutting-edge technologies. To achieve global health goals like the Sustainable Development Goals, continuous research, funding, and international cooperation are essential.

Conclusion

In conclusion, vector control is a complex and multifaceted issue that requires effective communication, cultural understanding, and effective communication strategies to effectively combat vector-borne diseases.

Vector control initiatives must take a comprehensive and community-focused approach to address behavioral issues and promote effective vector control strategies

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Internet Resources

Centers for Disease Control and Prevention (CDC), U.S.

Global Chagas Disease Coalition

International Federation of Associations of People Affected by Chagas Disease (FINDECHAGAS)