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Epidemiology of malaria in India and the persistent barriers to Its control: A review

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Abstract
Malaria continues to pose a formidable challenge to public health in India despite sustained efforts to control and eliminate it. Although there has been a notable decline in the reported number of cases and deaths over the last two decades, the disease remains endemic in several parts of the country. This review presents a comprehensive account of the current epidemiological trends of malaria in India, examining the species distribution, transmission patterns, regional diversity, and seasonal variations. Furthermore, the review explores the persistent obstacles impeding malaria control, such as insecticide and drug resistance, climate-driven transmission dynamics, inadequate health infrastructure, and socio-economic disparities. In light of these challenges, it is evident that while policy frameworks and strategic action plans have been established, their full implementation remains fragmented. The article underscores the need for integrated interventions combining conventional public health strategies with modern technological innovations, alongside stronger political commitment and community engagement to accelerate progress toward malaria elimination.

Keywords: Malaria, India, epidemiology, vector control, *Plasmodium falciparum*, *Plasmodium vivax*, drug resistance, surveillance, public health

Introduction

Malaria has long been entrenched as a major vector-borne disease in India, accounting for significant morbidity and mortality, particularly among vulnerable populations such as children, pregnant women, and marginalized tribal communities. According to the World Health Organization (2023) [10], India represented nearly 66% of malaria cases in the South-East Asia Region. Although annual malaria cases have declined from over two million in the early 2000s to fewer than 200,000 in 2022, the disease remains a threat in many districts, primarily due to uneven implementation of control measures, emerging resistance, and environmental factors favoring vector proliferation.

Epidemiological Profile of Malaria in India

India's malaria landscape is characterized by the presence of two dominant species of the parasite, *Plasmodium falciparum* and *P. vivax*. These species differ in their clinical severity, relapse patterns, and geographical dominance. *P. falciparum* is predominantly found in forested tribal regions and central India, whereas *P. vivax* tends to be more common in urban and peri-urban areas. The following table compares key features of the two species relevant to malaria epidemiology in India:

Table 1. Comparison of *Plasmodium falciparum* and *P. vivax* in India

Characteristic	*P. falciparum*	*P. vivax*
Prevalence (%)	~60% of total cases	~40% of total cases
Geographical distribution	Central, eastern, tribal regions	Urban and northwestern regions
Clinical severity	Severe and potentially fatal	Generally milder, relapsing
Relapse potential	No	Yes (via hypnozoites in liver)
Drug resistance	Widespread resistance reported	Chloroquine resistance emerging
Seasonality	Peaks in monsoon/post-monsoon	Peaks in monsoon/post-monsoon

The peak transmission season in India coincides with the monsoon months of June to September, during which increased rainfall creates ideal breeding conditions for the primary vectors—*Anopheles culicifacies* in rural areas and *Anopheles stephensi* in urban settings. Malaria burden remains highest in the central Indian states such as Chhattisgarh, Madhya Pradesh, Odisha, and Jharkhand, many of which are home to forested and tribal populations. Urban malaria has seen a resurgence in cities like Mumbai and Delhi, fueled by rapid urbanization, construction activities, poor waste management, and water stagnation.

Barriers to Malaria Control in India

Despite the National Framework for Malaria Elimination (2017–2027), several persistent barriers hinder the effective control and eventual elimination of malaria in India. Among the most significant is the development of insecticide resistance among vector populations. Routine use of DDT and pyrethroids in indoor residual spraying (IRS) and long-lasting insecticidal nets (LLINs) has led to reduced efficacy over time, with studies documenting resistance in *An. culicifacies* and *An. stephensi* across multiple regions (Raghavendra *et al*., 2017) [6]. This resistance compromises vector control interventions, allowing transmission to persist even in areas with high IRS coverage.

Drug resistance, especially among *P. falciparum*, is another major challenge. Resistance to chloroquine and sulfadoxine-pyrimethamine forced a policy shift toward artemisinin-based combination therapy (ACT). However, delayed parasite clearance times have raised alarms about emerging

artemisinin resistance, particularly in the northeastern border states, which share ecological and socio-political similarities with Southeast Asia's resistance hotspots (Das *et al*., 2022) [2].

Compounding these biological challenges are systemic gaps in the healthcare infrastructure, especially in remote and tribal areas where malaria is most endemic. The lack of trained personnel, irregular drug supplies, limited diagnostic access, and poor transportation networks significantly delay diagnosis and treatment. Passive surveillance mechanisms further underestimate the true disease burden. Surveillance is often limited to public health facilities, with little integration of private sector data. This fragmented approach hampers timely outbreak response and resource allocation (Anvikar *et al*., 2021) [1].

Socio-economic disparities also play a substantial role. Populations living in poverty, especially seasonal migrants and tribal communities, often lack access to preventive measures and healthcare services. Poor housing conditions and low literacy impede the adoption of personal protection practices. Moreover, behavioral factors such as reluctance to use bed nets or seek prompt treatment contribute to transmission persistence (Sharma *et al*., 2020) [7]

National Control Programs and Technological Advances

India's malaria elimination roadmap includes expanding diagnostic services, ensuring universal access to ACTs, distributing LLINs in endemic areas, conducting regular IRS, and strengthening surveillance. The plan also emphasizes inter-sectoral collaboration and community engagement. Despite these efforts, progress has been uneven, and resource allocation remains a limiting factor in high-transmission districts.

On a positive note, the integration of digital health tools and spatial technologies has improved surveillance capacity. Mobile-based data reporting, geographic information systems (GIS), and predictive modeling using artificial intelligence (AI) are being piloted in various states to identify hotspots and direct interventions. In addition, genomic surveillance is being used to track parasite mutations and monitor drug resistance trends (Sundararajan *et al*., 2023) [9].

Conclusion

Malaria continues to challenge India's public health system despite significant progress in reducing its incidence. The complexity of malaria transmission in India driven by ecological diversity, socio-economic inequality, vector and parasite resistance, and operational hurdles necessitates a more nuanced and sustained approach. A combination of robust surveillance, universal access to effective treatment, insecticide resistance management, socio-economic upliftment, and technological innovation is vital to achieving malaria elimination by 2030. Success will ultimately depend on political will, sustained funding, and community participation.

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