



## Current status on malaria prevalence and distribution in India

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### Abstract

Mosquitoes transmit a wide range of diseases to humans and other animals; the World Health Organization considers mosquitoes to be humans' number one enemy. Various mosquito species such as *Aedes*, *Anopheles*, and *Culex* spread the dreaded disease such as brain fever, chikungunya, dengue fever, filariasis, hemorrhagic fever, Japanese encephalitis, malaria, yellow fever and Zika. Mosquito-borne infections cause major economic concerns for people. The current study examines year and state-by-state data on malaria cases from 2020 to 2024 (up to August). According to National Center for Vector Borne Disease Control (NCVBDC) data, expressed 1,86,532 cases of malaria fever were registered in 2020, resulting in 98 fatalities, similarly, 1,61,752 malaria infected cases recorded among 90 deaths noted in 2021. Likewise, 1,76,522 cases were recorded, with 83 deaths recorded in 2022, in the year 2023, totally 2,27,564 cases with 83 mortalities recorded. In the current situation, 1,51,519 people have been infected, with 34 deaths documented up until August, 2024. These data clearly reveal an elevated prevalence of malaria infections in India.

**Keywords:** Vector-borne diseases, mosquito, malaria, situation analysis, *Plasmodium*, *Aedes*, *Anopheles*, and *Culex*

### Introduction

Various mosquito species such as *Aedes*, *Anopheles* and *Culex* spread many infectious to human includes dengue, yellow fever, chikungunya, Zika, malaria, Japanese encephalitis, West Nile fever, avian malaria, and elephantiasis (diseases and causative agent given graphically in Figure.1) (Dass and Mariappan, 1998; Tolle. 2009) [5, 46] amongst *Anopheles* species spread malaria and filariasis. Approximately 530 *Anopheles* species are recognized; however, only 30-60 species of *Anopheles* transmit malaria (Van Dung *et al.*, 2023) [47] and filariasis transmitted by *Anopheles gambiae*, *Anopheles flavirostris*, and *Anopheles barbirostris* (Datta Mudi *et al.*, 2024) [14]. Among malaria is a neglected tropical infection (Lobo *et al.*, 2011) [21].

Malaria is a potentially fatal disease caused by *Plasmodium* protozoa parasites. The worldwide prevalence of malaria has been estimated to be between 100 to 400 million cases, predominantly in tropical and subtropical countries (Saili *et al.*, 2023) [37]. Malaria is caused by five species of *Plasmodium* parasites: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*, and *Plasmodium knowlesi*, which are spread through the bite of infected female *Anopheles* mosquitoes (Figure.2). *Plasmodium falciparum* is the deadliest malaria parasite, while *Plasmodium vivax* is the most prevalent. Malaria can also spread by infected needles and blood transfusions (Kumar *et al.*, 2022) [20].

Malaria vectors also include *An. gambiae*, *An. arabiensis*, *An. coluzzii*, *An. funestus*, *An. nili*, and *An. moucheti* (Msugupakulya *et al.* 2023) [24], while other species involved in malaria transmission include *An. carnevalei*, *An. coustani*, *An. hancocki*, *An. leasoni*, *An. marshallii*, *An. melas*, *An. paludis*, *An. pharoensis*, *An. ovengensis*. *An.*

*wellcomei*, *An. rufipes*, and *An. ziemanni* (Kamiya *et al.* 2020) [19]. Malaria can be preventable and curable.

### Malaria situation in India

Malaria is a major public health issue in various Indian states. In India, about 44 percent of reported malaria cases and 43% of deaths are disproportionately attributed to approximately 27 tribal-dominated areas that account for 5% of the population. 57.3% of these cases are classified as *Plasmodium falciparum* infections (Rajvanshi *et al.*, 2020; Singh *et al.*, 2024) [32, 43].

An estimated 330 million people lived in India in 1947, the year of its independence, and 75 million of them had malaria. Malaria cases dramatically decreased to barely 100,000 in 1964, marking a remarkable accomplishment on the eradication front during the late 1950s and early 1960s. But there was a reverse, and malaria made a reappearance. The number of cases of malaria had reached 6.4 million by 1976 (Mishra *et al.*, 2021) [23].

In 2020 1,86,532 cases of malaria fever were registered, resulting in 98 fatalities, among Odisha (41,739), Chhattisgarh (36,667) Uttar Pradesh (28,668) Jharkhand (16,653) highest number of malaria cases registered with Chhattisgarh, 34 and Maharashtra 12 highest deaths rate registries (Table.1)

Similarly, in 2021, Chhattisgarh, 29,733, West Bengal, 28,987, Odisha 25,503 and Maharashtra, 19,303 infected cases recorded, and totally countrywide 1,61,752 malaria infected cases recorded with 90 deaths (Table.1).

In 2022, 1,76,522 cases were recorded, with 83 deaths noted, which West Bengal (40,594), Chhattisgarh (30,029), Odisha (23,770) and Jharkhand (19,167) were consistent with the highest number of suspected cases of malaria. However the highest number of mortality were reported

Maharashtra (26), Jharkhand (20) and Mizoram (10) (Table.1)

Likewise in the year 2023, totally 2,27,564 cases with 83 mortalities recorded with Odisha (41,973), Jharkhand (34,087), Chhattisgarh (31,706) and West Bengal (26,493) malaria cases registered (Table.1).

In the current condition, 1,51,519 people have been infected, with 34 deaths documented up until August, 2024 (Table.1). Last five years data of malaria cases and mortality in Indian states (2020 – 2024) expressed in the figure 3. Among all the states in India, only significant states have been found to have high malaria cases and deaths, the main reason for which is the hygiene status of the states, Malaria prevalence in India states is shown in the map in different colors (Figure.4). National Center for Vector Borne Disease Control, data clearly reveal an elevated prevalence of malaria infections in India (Table.1).

### Malaria's social and geographic distribution in India

People of all ages and genders are affected by malaria, while pregnant women and children are at high risk. The country undergoes the monsoon from June to September, which is marked by intense rainfall in many regions. The collecting of rainwater, which encourages mosquito hatching, is the main cause of malaria transmission (Mishra *et al.*, 2021; Ranjha *et al.*, 2023)<sup>[23, 36]</sup>.

In India, malaria is more perennially transmitted, particularly common in the northeast, eastern, and central regions of India. Numerous variables, including hilly and forested areas, a large number of slow-moving streams, a lack of access to health facilities, and multiethnicity, many of whom are financially low, are partially responsible for this. Additionally, the tribal and marginalized population has a poor level of community awareness on malaria prevention and management (Villena *et al.*, 2024)<sup>[48]</sup>.

The majority of malaria confirmed cases are eco-epidemiological scenario described. The ongoing migration and migration of inhabitants from neighbouring countries and states with moderate to high malaria endemicity also plays a role (Sharma *et al.*, 2021)<sup>[39]</sup>.

Malaria occurs in India in both local and focused areas, and progress toward lowering malaria mortality and morbidity remains fragile, because of attributed to poor health facilities and deteriorating surveillance and logistics in many sections of the country (Thellier *et al.*, 2024)<sup>[45]</sup>.

### Malaria one of the most serious public health issues in the world

Malaria remains one of the world's major public health problems, with an anticipated 249 million infections and 608,000 malaria-related fatalities and 100 000 population at risk reported in 2022. African countries account for around 94% of global malaria infections, with 2% coming from countries in the World Health Organization's (WHO) South-East Asia (SEA) region. India was responsible for nearly 66% of malaria cases in the WHO SEA region in 2022 (WHO, 2022; Singh *et al.*, 2022; WHO, 2023)<sup>[41, 42, 49, 50]</sup>.

### Malaria diagnosis and confirmation test

#### Blood smear microscopy test

A little amount of blood is drawn from a patient and examined under a microscope. Identify malarial pathogens (Maqsood *et al.*, 2021)<sup>[22]</sup>.

### Rapid Diagnostic Test (RDTs)

A drop of patient blood sample was mixed with a lysing agent and placed on the test card. The results shown on a dipstick or rapid test cassette on two lines indicate that the person will test positive. If malaria antigens are not present, the person will test negative (Cunningham *et al.*, 2019)<sup>[4]</sup>.

### PCR test

PCR tests, or polymerase chain reaction tests, are also available to detect malaria parasites.

Blood, saliva, mucus, or tissue sample obtain from patient. A thermal cycler contains the sample, an enzyme known as polymerase, and specific chemicals. Using heating and cooling cycles, this machine replicates a specific section of DNA. After about an hour, billions of copies are generated. The equipment will display the malarial pathogens that are present. An advantage is that PCR tests can confirm the exact species of malaria parasite (Berzosa *et al.*, 2018)<sup>[1]</sup>.

### Status of drug resistance

In the WHO South-East Asia Region first-line treatments for *P. falciparum* malaria include artemether-lumefantrine (AL), artesunate-mefloquine (AS-MQ), artesunate pyronaridine (AS-PY), artesunate plus sulfadoxine-pyrimethamine (AS+SP), and dihydroartemisinin-piperaquine (DHA-PPQ). Therapeutic efficacy studies (TES) of AL in Bangladesh, India, and Myanmar from 2015 to 2020 found high efficacy with all treatments. In India, treatment failure rates with AS+SP were low. However, one study in Chhattisgarh found a significant incidence of dhfr and dhps mutations, indicating lesser sensitivity to the companion medication, SP (Rahmasari *et al.*, 2022; Nallapati *et al.*, 2024)<sup>[25, 31]</sup>.

### Recommendation of malaria vaccine

WHO recommended that the RTS, S/AS01 malaria vaccine be piloted in selected parts of three African country - Ghana, Kenya, and Malawi - beginning in January 2016. Pilot data suggest that the vaccine has an excellent safety record, reduces severe, fatal malaria, and can be provided efficiently in practical applications childhood vaccination, even during a pandemic. On October 6, 2021, the World Health Organization advised using the RTS, S and R21 malaria vaccine for children and pregnancy women to prevent the *Plasmodium* parasites (Duffy, 2022; Stanicic, 2023; Duffy *et al.*, 2024)<sup>[15, 16, 44]</sup>

### Chances and challenges in vector control programs

Different strategies have been used to eradicate or reduce malaria vector *Anopheles* species populations, with varying levels of success. Previous publications extensively reviewed and discussed the efficiency and sustainability of specific approaches, including community-based control programs and vector control program-driven space spraying with chemical insecticides such as permethrin, sumithrin (d-phenothrin), deltamethrin, and mosquito coils (Henrick, 2007; Popivanov *et al.*, 2015; Shroff *et al.*, 2021)<sup>[18, 28, 40]</sup>. These chemical insecticides, non-biodegradable, pollute the environment, are toxic to cohabitate, and lead to acute disorders, including vomiting and eye irritation (Billingsley *et al.*, 2020)<sup>[3]</sup>. Biopesticides derived from plants have emerged as viable alternatives to synthetic pesticides for vector control, as evidenced by recent systematic studies that reached differing results on the utility of community-

based methods (Dass, 2014; Dass and Mariappan, 2014; Dass and Mariappan 2014) [7, 9]; Dass and Mariappan, 2016) [8]; Dass *et al.*, 2022a; Dass *et al.*, 2022b, Dass, 2024) [10, 11, 12]. Synthesized silver and gold nanoparticles have the potential for control mosquito vectors (Dass, 2015; Dass and Mariappan, 2018; Dass, 2020; Shabab *et al.* 2022; Prabhakaran *et al.* 2023) [6, 29, 38]

**Malaria control programs**

Roll Back Malaria (RBM) Partnership is a worldwide campaign to reduce malaria mortality, whereas the President's Malaria campaign (PMI) is a US-led program to control malaria in Africa, as well as National Malaria Control Programs (NMCPs), which are country-level programs that execute malaria prevention activities. WHO NTD Control Program insists on a global endeavor to eliminate NTDs. The National Vector Borne Disease Control Program (NVBDCP) in India focuses on malaria control (Rajvanshi *et al.*, 2021; Rajvanshi *et al.*, 2024) [33, 34, 35].

**Vector control programs confront several problems that reduce their effectiveness**

Insecticide resistance is a significant difficulty in vector management, as vectors have genetic alterations because of pesticides. Changing vector behaviours, such as outdoor biting. Changed ecosystems and disease transmission. Increased vector populations in urban areas. Migration and travel facilitate disease transmission. Multiple vector species are involved. There is a limited budget for vector control activities (Pradhan *et al.*, 2019; Rajvanshi *et al.*, 2024) [30, 35]. The challenge in finding potentially effective substances, and their inadequate characterization, a lack of knowledge about the structure of active secondary metabolites responsible for mosquito larvicidal activities are the primary causes of plant-based pesticide failure. The toxicity of pesticides is regarded as one of the most essential safeguards for the environment in mosquito control efforts (Dass, 2022) [10].

**Conclusion**

India is one of the most at risk for vector-borne diseases due to its tropical climate, dense urbanization, and poor

sanitation. The data presented here clearly reveals a large frequency of malaria infections in the country.

In the future, there will be a greater emphasis on the production, study, and application of pesticides derived from natural materials, as well as the delivery of dangerous plant-derived compounds. It is recommended that insecticides be developed using a mixture of compounds with similar target specificity.

To explore the harmful effects of plant bio-chemicals on non-target species through simulated and small-scale field trials. Researchers should examine and elaborate on the mechanism of action of isolated plant chemicals, which is usually lacking in research articles. Bioactive molecules are thought to be the principal cause of larval death, and the major key active chemicals should be extracted and studied in the future. It is also recommended that plant key active compounds that have been combined and manufactured be commercialized.

Eliminate vector habitats by implementing changes to the environment. Balance vector control with ecological considerations. Use organic methods to control vector populations. Encourage sustainable agriculture techniques. Allocate adequate resources for vector control. Consider climate change's effects on vector-borne diseases. Allocate sufficient amount for vector control activities.

**Data availability**

National Center for Vector Borne Disease Control (NCVBDC)

**Funding source**

Not applicable.

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that no conflict of interest.

**Table 1:** Year wise confirmed and mortality cases of malaria in Indian states

SN	States/UTs.	2020		2021		2022		2023		2024 (Upto August)	
		Malaria Cases	Deaths	Malaria Cases	Deaths	Malaria Cases	Deaths	Malaria Cases	Deaths	Malaria Cases	Deaths
1	Andhra Pradesh	2027	0	1315	0	2022	0	5268	0	4904	0
2	Arunachal Pradesh	33	0	8	0	18	0	11	0	8	0
3	Assam	484	2	162	0	280	0	567	0	694	6
4	Bihar	518	0	647	0	578	0	1257	0	400	0
5	Chhattisgarh	36667	34	29733	38	30029	20	31706	15	21764	0
6	Goa	102	0	90	0	587	0	1346	0	522	0
7	Gujarat	4771	1	4921	0	4785	0	4311	1	2009	0
8	Haryana	111	0	54	0	52	0	85	0	270	0
9	Himachal Pradesh	34	0	15	0	12	0	23	0	17	0
10	Jharkhand	16653	8	14198	0	19167	4	34087	2	21137	0
11	Karnataka	1701	1	913	2	289	0	275	2	453	1
12	Kerala	268	1	309	1	439	0	569	7	621	4
13	Madhya Pradesh	6760	1	3181	2	3826	0	3794	0	2065	0
14	Maharashtra	15215	12	19303	14	15451	26	16159	19	12624	11
15	Manipur	36	2	19	0	30	0	34	0	34	0
16	Meghalaya	2018	4	491	3	479	8	1755	14	489	2

17	Mizoram	7781	6	8018	10	11156	10	18077	13	14487	0
18	Nagaland	12	0	8	0	9	0	10	0	7	0
19	Odisha	41739	9	25503	13	23770	5	41973	4	44344	5
20	Punjab	109	0	71	0	119	2	75	0	182	0
21	Rajasthan	1276	0	925	0	1565	1	2263	0	729	0
22	Sikkim	4	0	4	0	8	0	6	0	5	0
23	Tamil Nadu	891	0	772	0	354	0	385	0	237	0
24	Telangana	870	0	874	0	611	0	420	0	197	0
25	Tripura	3395	2	10136	4	12771	3	22412	1	8325	0
26	Uttar Pradesh	28668	0	10792	0	7039	0	13603	0	5164	0
27	Uttarakhand	15	0	13	0	19	0	24	0	128	0
28	West Bengal	14049	7	28987	3	40594	3	26493	2	9116	5
29	Andaman and Nicobar Islands	85	2	27	0	50	0	42	0	82	0
30	Chandigarh	7	0	6	0	2	0	2	0	87	0
31	Delhi	135	1	167	0	263	1	344	1	232	0
32	Jammu And Kashmir	37	0	31	0	35	0	44	0	62	0
33	Ladakh	0	0	0	0	2	0	10	1	7	0
34	Lakshadweep	6	0	1	0	0	0	0	0	0	0
35	Puducherry	15	0	5	0	0	0	6	0	9	0
36	The Dadra and Nagar Haveli and Daman and Diu	0	0	54	0	111	0	128	1	108	0
	<b>TOTAL</b>	<b>186532</b>	<b>93</b>	<b>161753</b>	<b>90</b>	<b>176522</b>	<b>83</b>	<b>227564</b>	<b>83</b>	<b>151519</b>	<b>34</b>

Source: National Center for Vector Borne Disease Control (NCVBDC).

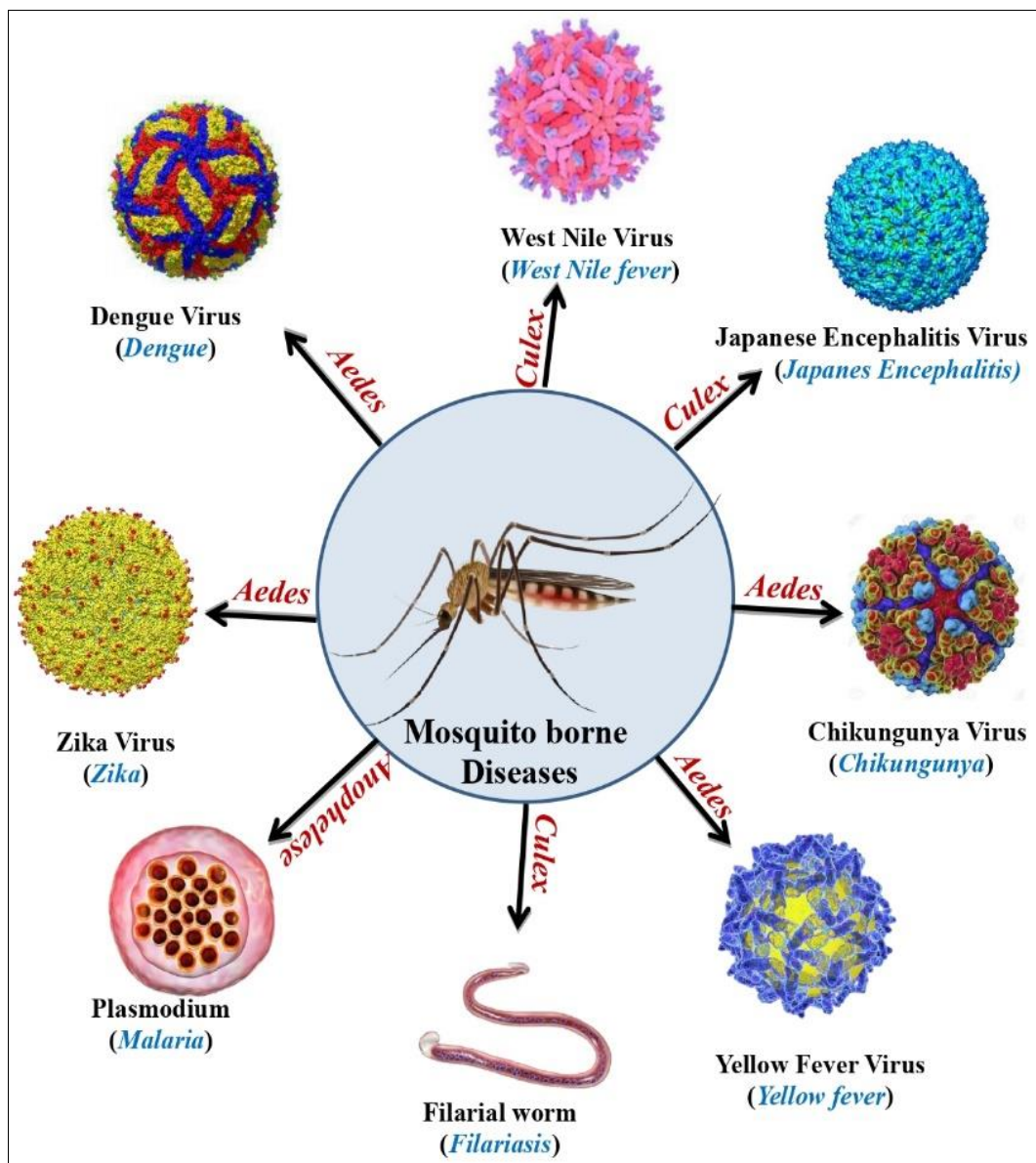


Fig 1: Mosquito borne diseases

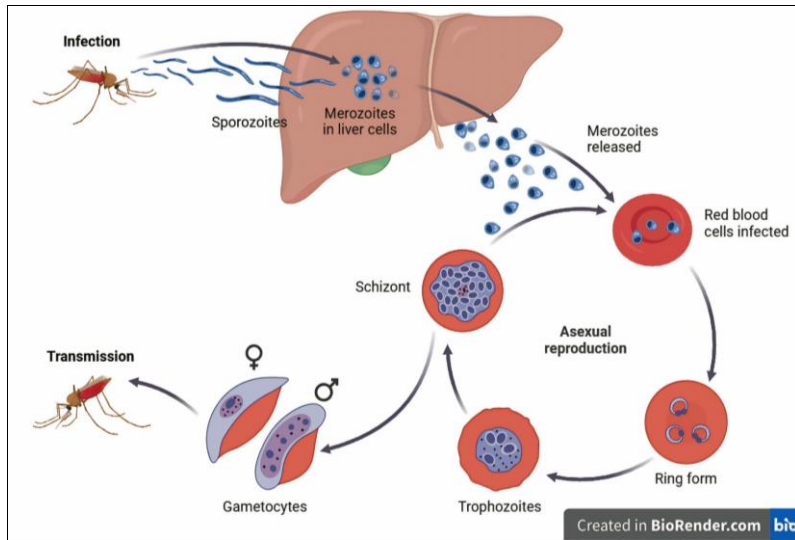


Fig 2: Transmission of *plasmodium* from infected female *Anopheles* to human

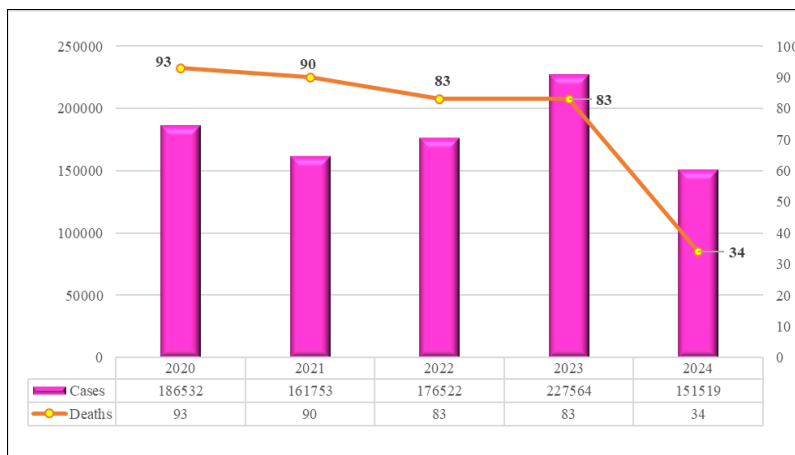


Fig 3: Five years data of malaria cases and mortality in India 2020 – 2024 (NCVBDC)

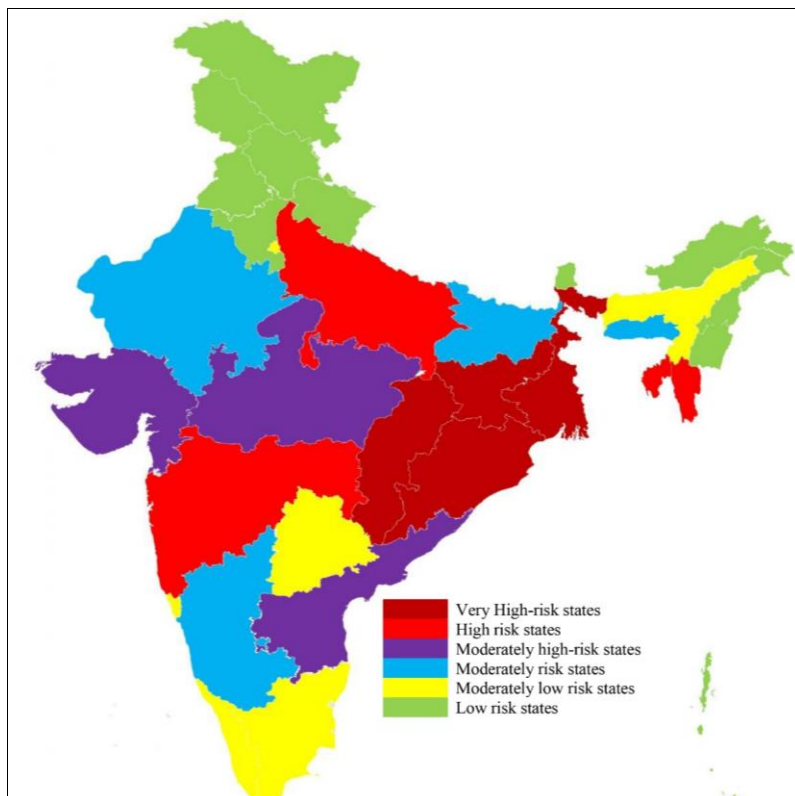


Fig 4: Malaria prevalence in India states from 2020 to 2024 (NCVBDC)

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