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Review Article

Transition of Malaria Control to Malaria Elimination in India

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A B S T R A C T

India achieved spectacular gains in malaria control during the 'Eradication Era' in the 1950s till the mid-1960s. The Global Malaria Eradication Programme of WHO launched in the 1950s was a huge success in India with the incidence dropping from an estimated 75 million cases and 8,00,000 deaths in 1947 to just 49,151 cases and no deaths in 1961 and malaria was thought to be on the verge of eradication. Thus, since the early 1950s, the malaria program in India has produced a number of successes, and has faced some setbacks also which have led to malaria resurgences. Recently, India envisages eliminating malaria by 2030 in line with the Global Technical Strategy (2016-2030). The National Framework for Malaria Elimination was launched in 2016 and National Strategic Plan 2017-2022 in 2017, provide a phased approach to elimination and outline priority areas and activities required to be implemented based on district-level stratification of burden. Malaria program is now moving away from "One Fit Size to All". States and districts are classified in four categories to eliminate malaria in a phased manner. In 2019, India recorded a 60% reduction in reported cases compared with 2017 and a 46% reduction compared with 2018. India's progress for drastic reduction of malaria incidences have also mentioned in World Malaria Report 2018, 2019 and 2020. However, there are challenges for the country to sustain the progress made so far and to accelerate further malaria activities to achieve the goal for malaria elimination by 2030. Since the discovery of malaria transmission was made in India by Sir Ronald Ross in 1897, an intensive works was carried on malaria control in India. There were different phases for malaria control in the country to moving from control towards eradication and elimination. The paper gives a brief history of malaria control in India and analyses the present malaria situation.

Keywords: Malaria, India, *Plasmodium Vivax*, Falciparum, Vector Control, Elimination

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Introduction

Malaria is preventable and treatable, and increased efforts are helping to reduce the disease burden in many areas. The World Health Assembly approved the Global Technical Strategy (GTS)[1] for Malaria Elimination 2016-2030 in May 2015, which establishes explicit global goals, milestones, and targets until 2030. In accord with the GTS, the Hon'ble Prime Minister of India was among the 18 leaders, who endorsed the Asia Pacific Leaders Malaria Alliance (APLMA) for malaria elimination roadmap at the East Asia Summit held in Kuala Lumpur, Malaysia, in November 2015, and agreed to the goal of a region free of malaria by 2030. National Vector Borne Disease Control Programme (NVBDCP), Ministry of Health & Family Welfare, Government of India launched the National Framework for Malaria Elimination (NFME)[2] on 11 February 2016 towards commitment to malaria elimination by 2030. Malaria elimination in India will be carried out in a phased manner. The National Strategy Plan 2017-2022[3] has been developed in alignment with NFME. This strategy sets ambitious but attainable goals for 2030, with milestones along the way to track progress. Sustainable Development Goals (SDGs) also talks of accessibility and equity of health services with the targets of ending the epidemics of AIDS, TB, malaria, and NTDs by 2030.

Malaria is still a major public health issue around the world. According to the World Malaria Report (WMR) 2020,[4] global malaria mortality fell by 60% over the period 2000 to 2019. The South-East Asian countries achieved the most progress, with 73% and 74% decreases in cases and deaths, respectively. World Malaria Reports[4,5] also reported the progress of India in the fight against malaria; 24% and 28% reduction of malaria cases in 2018 and 2019 reports, respectively. As per WMR 2020,[6] India contributed only 2% of malaria cases globally in 2019. It contributed to the largest absolute reductions in the WHO South-East Asia Region, from about 20 million cases in 2000 to about 5.6 million in 2019. However, in SEARO, India still accounted for about 88% of malaria cases in this region. Despite being the highest-burden country in the region, in 2019, India recorded a 60% reduction in reported cases compared with 2017 and a 46% reduction compared with 2018.

However, there are various challenges in achieving zero indigenous cases in all states and Union Territories (UTs) as per the malaria elimination goal set at NFME. Malaria transmission in India is complex and has more problems in high burden states due to being predominated by marginalised populations and tribal belts.[7,8] In the past, India has reported a high malaria incidence of even up to 75-100 million malaria cases and 0.8-1 million deaths reported annually in the 1930s, but in 1961, malaria was thought to be on the verge of eradication. These gains were, unfortunately, not sustained and malaria re-emerged after 1965. In recent years, although a drastic reduction of reported as well as estimated cases and deaths have been reported,[4-6] however, it is a challenge for the country to sustain the goal achieved so far and to accelerate further malaria activities to achieve the goal of malaria elimination by 2030. Since the discovery of malaria transmission was made in India by Sir Ronald Ross in 1897, intensive work was carried out on malaria control in India. There were different phases for malaria control in the country to move from control towards eradication and elimination. The journey of malaria control in India towards elimination has been reviewed and outlined in this article.

Material & Method

The National Vector Borne Disease Control Programme (NVBDCP) collects and compiles data on malaria both monthly and annually from all the 36 states and UTs for monitoring the trends and taking public health actions and planning. According to the Census of India, 2011,[9] the country is administratively divided into 28 states and 7 UTs. The retrospective NVBDCP data of malaria cases and deaths along with other important malaria indicators such as total blood slide examined, total malaria positive cases, *Plasmodium falciparum* (Pf) and *Plasmodium vivax* (Pv) cases have been considered and analysed. Published papers and reported incidence of malaria by the malaria programme in different phases in the country have also been systematically reviewed.

History of Malaria Control in India

In the early 1900s, malaria control operations in India were centred on the control of mosquito breeding. Till 1909, due to various reasons, experiments on the control of malaria were almost considered a failure, therefore, a further focus was concentrated on research and development in 1910.[10] Meanwhile, the Malaria Institute of India was established at Kasauli in 1909 as Central Malaria Bureau. In 1927, it was expanded and renamed the Malaria Survey of India. The organisation was shifted to Delhi in 1938 and was called the Malaria Institute of India. This institute conducted extensive research related to malaria along with a training programme in malariology for national and international personnel. During the Second World War, this was the only training centre in the world and hundreds of professionals were trained here. During the period from 1910 to 1936, the fight against malaria continued by control of mosquito breeding using larvicides like Paris green and oil. Besides this, some minor engineering measures were encouraged such as drainage and filling up of pits and other water collection areas. By this time, various examples of successful malaria control were seen in limited areas. Adult control using space spraying with pyrethrum extract was added as a control intervention only around the 1930s (1934-35) when evidence in favour of the same emerged from other

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countries.[10] In 1935, it was estimated that 100 million malaria cases and 1 million deaths had occurred in India.

Soon after the Second World War, DDT was released for use in public health. Trails with DDT were started in India in 1945. For the first time, a cost-effective tool became available for mass application to interrupt malaria transmission among rural and other communities. In 1947, when India became independent, 75 million malaria cases in a population of 330 million (21.8% population) were estimated with some 800,000 deaths.[11] By 1948, several states were showing spectacular effects of DDT in malaria control. Thus, a countrywide comprehensive programme to control malaria was recommended in 1946 by the Bhore committee report that was endorsed by the Planning Commission in 1951. With this background, the National Malaria Control Program (NMCP) was launched in the country in 1953 (Table 1).[10] Indoor residual spraying, monitoring and surveillance of cases, and antimalarial treatment of patients were the key activities implemented under this programme. This programme achieved remarkable results in causing a decline in malaria-related morbidity and mortality and there was a general reduction in malaria epidemiological parameters. The five years of NMCP operations achieved remarkable success in malaria control, therefore, the focus of the malaria programme was shifted from control to eradication (Figure 1). The success of NMCP in 1953-1957 in consonance with the global thinking reflected by the deliberation of WHO resulted in the creation of a separate Directorate of National Malaria Eradication Programme in 1958 for the eradication of malaria from the country. Thus, the National Malaria Eradication Programme (NMEP) was launched in India in 1958, which was the single largest health programme in the world. In accordance with WHO's malaria eradication policy, the NMEP comprised four phases: the preparatory phase, attack phase, consolidation phase, and maintenance phase.

Table 1.Journey of Malaria Control Programme to Elimination in India

Prior to 1940	No organised National Malaria Control Programme
1945	Insecticide properties of DDT identified
Prior to 1953	Estimated malaria cases in India - 75 million estimated deaths due to malaria - 1 million
1953	Launching of National Malaria Control Programme
1958	Launching of National Malaria Eradication Programme
1965	Cases reduced to 0.1 million
Early	70s Resurgence of malaria in some towns and cities
1976	Malaria cases (6.46 million) highest in post DDT era (one of the reasons for resurgence was insecticide resistance in malaria vectors)
1977	Modified Plan of Operations (MPO) implemented
1984-1998	Annual reported incidence within 2-3 million cases
1994	Resurgence of malaria in some states
1995	Modified Action Plan (MAP) for malaria control implemented
1997	World Bank Assisted Enhanced Malaria Control Project (EMCP) launched
1998	Malaria programme renamed as National Anti-Malaria Programme (NAMP)
2003	Five more diseases added and NAMP renamed as National Vector Borne Disease Control Programme (NVBDCP)
2005	Global fund Assisted Intensified Malaria Control Project (IMCP) -100 millionpopulation in 94 districts of 10 states being covered from 2005-06
2006	World Bank Assisted Enhanced Vector Borne Diseases Control Project (EVBDCP) - 189 million population in 191 districts in 13 states
2015	India, in response to the Global call for malaria elimination by WHO (GTS 2016-2030), agreed to be a part of the APMLA and Eliminate malaria in India by 2030
2016	Launch of National Framework for Malaria Elimination (NFME) 2016-2030
2017	Launch of National Strategic Plan (NSP) for Malaria Elimination (2017-22)

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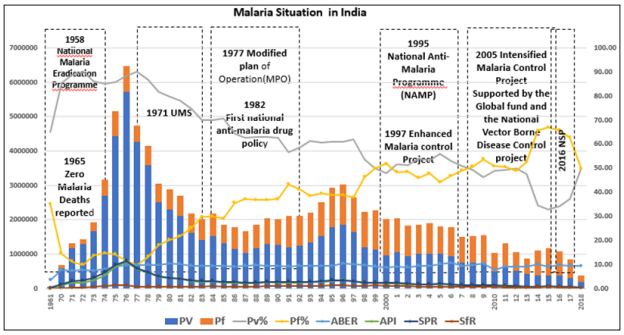

Figure 1.Malaria Epidemiological Parameters and History of Initiatives undertaken by the National Malaria Programme since 1961 in India

(Source: NVBDCP)

From this point, India achieved spectacular gains in malaria control during the 'Eradication Era' in the 1950s till mid-1960s. The Global Malaria Eradication Programme of WHO launched in the 1950s was a huge success in India as the incidence declined from an estimated 75 million cases and 8,00,000 deaths in 1947 (at the time of independence) to just 49,151 cases and no deaths in 1961 and malaria was thought to be on the verge of eradication.[12] Annual Parasite Incidence per thousand [API] was 0.13 and slide positivity rate [SPR] was 0.38%. By 1965, malaria had decreased to the point that just 0.02% of the population was infected, i.e. there were only 0.1 million cases of malaria and no deaths in a population of almost 466 million people.

However, malaria was reintroduced and spread widely due to a variety of factors, including slow development of health infrastructure, inadequate surveillance and monitoring, and logistical challenges.

After that, a series of setbacks were witnessed leading to malaria resurgence in the country and reported cases increased to 13,22,398 by 1971 (API: 2.47; SPR: 3.27%) and then to 64,67,215 in 1976 (API:11.25; SPR:11.6%). The failure was attributed to complacency, and administrative, operational, and technological issues such as vector resistance to the commonly used insecticide DDT and parasite resistance to chloroquine, as well as low priority malaria in the post-control period.[7]

However, an increasing trend of malaria was also observed in some towns/cities which led the Madhok Committee (1969) to recommend the implementation of effective anti-larval measures in urban areas. Accordingly, the Urban Malaria Scheme (UMS) was launched in 1971 (Figure 1) and it was envisaged that 131 towns would be covered under the scheme in a phased manner. Following that, in 1977, the Modified Plan of Operations (MPO)[13] was created, with a three-pronged strategy comprising government efforts, malaria research, and public participation. Consequent to the establishment of MPO, a thrust was provided in both basic and operational research. Further, *Plasmodium falciparum* Containment Programme (PfCP) was conceived as an additional input to contain the spread of resistant falciparum from its established foci in the north-east states to other parts of the country.[10] In its first few years, MPO was a 100% centrally sponsored programme, but with the passage of time, by the 1980s, programme expenditure was shared equally between the centre and states. Malaria incidence had decreased to approximately 2 million cases and 247 deaths by 1984.

In the following years, malaria control projects were launched in selected high endemic areas of the country with funds from the World Bank and the Global Fund. The Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) has been providing financial support to the Government of India for the Intensified Malaria Control Project (IMCP) since 2005 in high endemic states. Presently, IMEP is being implemented in 7 NE states (Arunachal Pradesh, Assam, Meghalaya, Mizoram, Nagaland, Manipur, and Tripura), and Madhya Pradesh within the existing framework of NVBDCP.

In the post-resurgence phase, for many decades, reported cases of malaria fluctuated between 1.5 and 3.0 million against the backdrop of the rising population of India. Subsequently, the programme was renamed as National Anti-Malaria Programme (NAMP) in 1998. Other vector-borne diseases like dengue, chikungunya, Japanese Encephalitis (JE), Lymphatic Filariasis, and Kala-azar were brought under this programme and, therefore, it was again renamed as "National Vector Borne Disease Control Programme" (NVBDCP), in 2003. Since 2005, NVBDCP is being implemented under the overarching umbrella of the National Rural Health Mission which has now been subsumed under the National Health Mission (NHM), incorporating the National Urban Health Mission (NUHM) as well.

The Government of India also has 19 Regional Offices for Health and Family Welfare (ROHFW), located in 19 states. One or more states are covered under the jurisdiction of each ROHFW. They play a critical role in NVBDCP activity monitoring in the states. Every state has a vector-borne disease control unit under its Department of Health and Family Welfare, headed by the State Programme Officer. Each state has a State Health Society at the state level and District Health Societies through which funds are disbursed. At the district level, the vector-borne disease control programme including malaria is managed by the District Malaria Officer (DMO) or District Vector Borne Disease Control Officer (DVBDCO).

Malaria Situation in India

The epidemiology of malaria in India is complex because of geographic and ecological diversity and the wide distribution of ten anopheline vectors. The two major

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malaria parasites in India are *Plasmodium falciparum* and *P. vivax*; both are unevenly distributed across India, though cases of *Plasmodium ovale* and *Plasmodium malariae* have also been reported from some parts of the country.

India has made significant progress in lowering the malaria burden during the last 15 years. The Slide Positive Rate (SPR) has also shown a gradual decline from 3.32 in 1995 to 0.26 in 2019 (NVBDCP data). Trends of malaria cases, deaths, and *Plasmodium falciparum* (Pf) and *Plasmodium vivax* (Pv) cases from 2000 to 2019 are graphically depicted in Figure 2 which shows a significant decline in cases as well as deaths in the country.

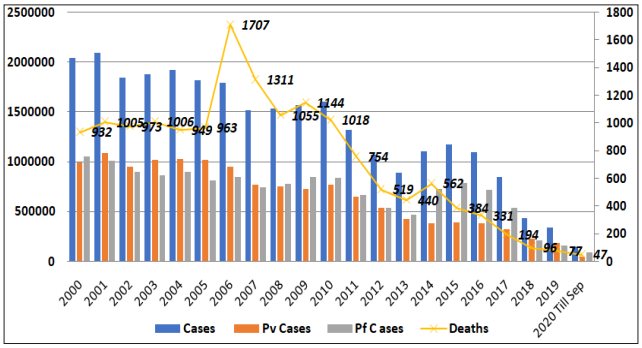

Figure 2.Trends of Malaria Cases, Deaths and Pf & Pv Cases from 2000

(Source: NVBDCP)

It is also to be noted that malaria is characterised by local and focal occurrences, and achievements in malaria mortality and morbidity remain very fragile (e.g. an increase in cases and deaths in 2014; and previously in 1976, a massive resurgence of malaria with 6.46 million cases from 0.1 million cases was attributed to inadequate health infrastructure and diminishing monitoring and logistics in many parts of the country). Recently, in 2018-19, focal outbreaks were experienced in Tripura, Mizoram, and Uttar Pradesh. With the emergence of newer challenges in terms of a possible threat of artemisinin resistance and insecticide resistance, India has a narrow window of time to eliminate malaria before the threats near the border of the country impede the journey to malaria elimination.

The trend of malaria cases, deaths, Pv and Pf since 2000 is given in Figure 2 while trends of API and SPR are shown in Figure 3. The above trends show that the API and Slide Positivity Rate (SPR) have declined from the year 2000 to 2019 while ABER is continuously maintained above 9%. However, the testing rates greatly varied among the states (0.2% - 29%), with states such as Bihar reporting an ABER of less than 1% and states such as Gujarat, Goa, and Mizoram reporting ABER greater than 20% in 2015, as per NVBDCP reported data. Bivalent RDTs were introduced in 2013, which resulted in an increase in testing, ABER, and the number of positive cases (Figure 3).

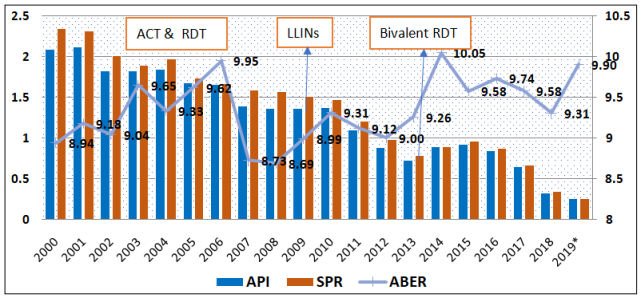

Figure 3.Trends of API, SPR and ABER from 2000 to 2019 in India and Introduction of New Tools under NVBDCP

The case load, which was stable at around 2 million cases per year in the late 1990s, has been falling since 2002. The SPR has also shown a gradual decline from 3.32 in 1995 to 0.26 in 2019. However, there is a fluctuation in the percentage of *Plasmodium falciparum* reported in the country, it has decreased from 64% in 2014 to 46.55% in 2019, which means the proportion of *P. falciparum* has decreased during the recent years (2018 and 2019). The Annual Parasite Incidence has consistently come down from 2.09 per thousand in 2001 to 0.26 per thousand in 2019, but confirmed deaths were fluctuating near 1000 till 2010 but in the last five years, there has been a significant decline in reported deaths due to malaria. Similarly, Pf cases have declined from 1.04 million to 0.15 million cases during the same period. SPR and Slide falciparum Rate (SFR) have reduced over the years 2001 to 2019. It is also observed that ABER has remained within the range of 10.05% to 8.73% during the period 2001 to 2019. There was a declining overall endemicity of malaria in the country.

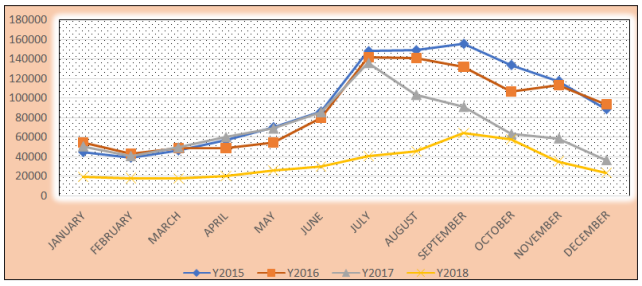

Figure 4.Seasonal Trend of Malaria Cases in India

In many places, transmission is seasonal (Figure 4), with the peak between July and October, during and just after the rainy season. From June to September, the country experiences monsoon characterised by heavy rains across different states; maximum transmission of malaria is due to the collection of rainwater that promotes mosquito breeding. Malaria in India especially in the north-eastern, eastern, and central parts of the country, recording more or less perennial transmission, is due to a number of factors, such as hilly and forest areas, number of slow-moving streams, conflict-affected areas, with inadequate access and

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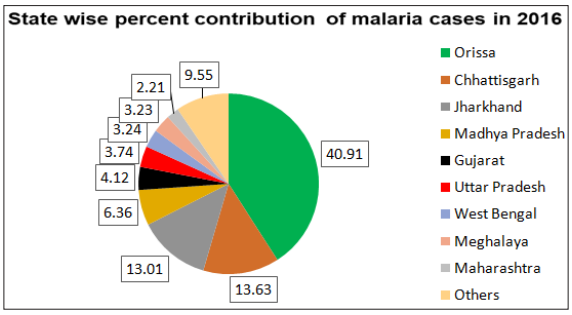
health infrastructure, and multi-ethnicity, many of whom are economically disadvantaged. There wasa flatteningof the seasonal curve in the year 2018, as malaria cases hadsignificantly declined in 2018 as compared to previous years.

Malaria Epidemiological Situations in 2018 and 2019

In 2018, the reported malaria cases nationwide declined by 49.09% (429928 cases) compared to 2017 (844,558 cases) and the malaria deaths were reduced by 50.52% from 194 in 2017 to 96 in 2018. Further, the malaria situation has been better in the country since 2019. Reported malaria cases (provisional) declined by 21.3% from 429928 in 2018 to 338515 in 2019 and deaths reduced by 19.79% from 96 in 2018 to 77 in 2019.

During the year 2019, the highest number of malaria cases were reported from Uttar Pradesh (27.4%) followed by Chhattisgarh (17.0%), Odisha (11.7%), Jharkhand (11.0%), West Bengal (7.7%), and other states, respectively as shown in Figure 5. These 5 states contributed 75.6% of malaria cases. However, in 2018, 73.27% of cases were contributed from these 5 states, namely Uttar Pradesh (20.12%), Chhattisgarh (18.31%), Odisha (15.42%), Jharkhand (13.28%), and West Bengal (6.15%). Odisha was the highest malaria burden state in the past.In 2016, 40% of malaria cases werecontributed only by this state. In 2019 and 2018, Uttar Pradesh became the highest malaria burden state in the country, while, the percent contribution of malaria cases in Madhya Pradesh reduced from 5.18% to 4.2% and in Gujarat from 5.14% to 4.1% in 2019.



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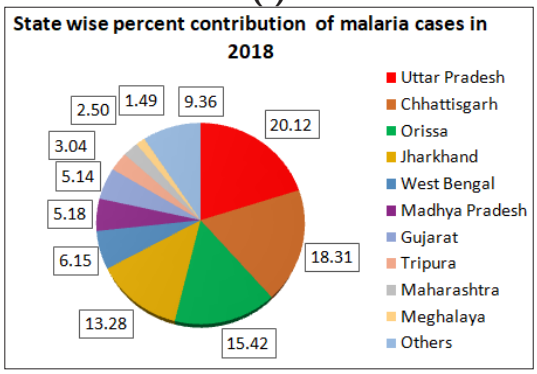

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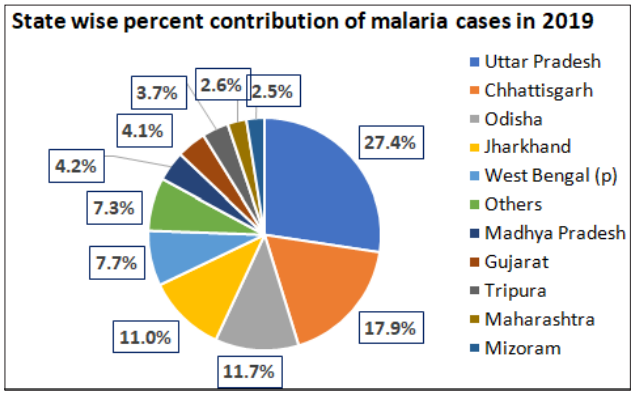

(c)

Figure 5.Statewise Per Cent Contribution of Malaria Cases in India during (a) 2016 (b) 2018 and (c)2019

A total of 77 deaths were reported in 2019 in the country, with the highest number (31) of malaria deaths (40.3%) having been reported from Chhattisgarh. This state also contributed the highest proportion (31.3%) of Pf cases in the country. This state is inhabited by ethnic tribes in forest ecosystems where stable malaria conditions occur. However, Odisha reported 3 deaths in 2018 and 9 deaths in 2019 (provisional NVBDCP data). A number of deaths due to malaria were also reported from Mizoram (8), Maharashtra (7), West Bengal (6), and 4 each from Assam and Meghalaya in 2019.

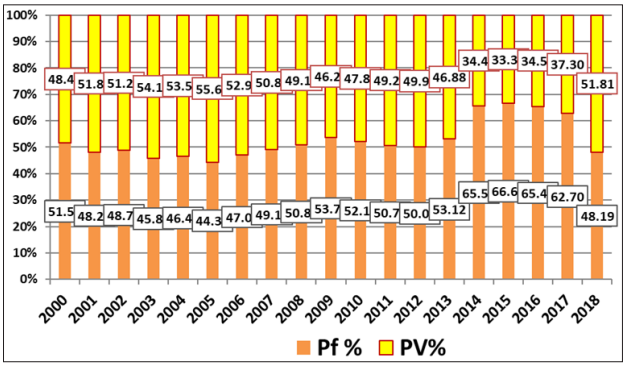

Figure 6.Statewise Per Cent Contribution of *P. falciparum* and *P. vivax* in India during 2019

Diagnosis is being done by using RDT as well as a microscope. RDT is mostly used at the community level by ASHAs and MPWs. A total of 101892 *P. vivax* and 156937 *P. falciparum* malaria cases were detected by using RDT in the country in the year 2019. In total, *P. vivax* proportion in the country during 2019 was 181578 (53.6%) while *P. falciparum* was 154698 (45.7%) while in 2018, the proportions of Pv and Pf were 51.81 and 48.19 respectively. Figure 6 shows that the Pf proportion in the country slightly increased in 2014, remained above 60% till 2017, and again declined in 2018 and 2019. The proportion of Pf malaria increased in 2018 and 2019. Some patients showed the presence of both parasites (Pv and Pf); the maximum proportion of mixed

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infection was reported from Chhattisgarh (67.2%) and Meghalaya (27.8%).

In 2019, maximum *Plasmodium falciparum* cases were found in Chhattisgarh (31.75%) followed by Odisha (22.96%), Jharkhand (12.29%), Uttar Pradesh (9.28%), Tripura (7.47%), Mizoram (4.99%), and Madhya Pradesh (2.26%). These 7 states contributed 90% of Pf cases in the country.

However, in 2019, maximum Pv cases were contributed from Uttar Pradesh (43.8%) followed by West Bengal (13.3%), Jharkhand (9.7%), and Gujarat (9.7%). Figure 7 showed the percentage contribution of Pf and Pv cases in different states/ UTs.

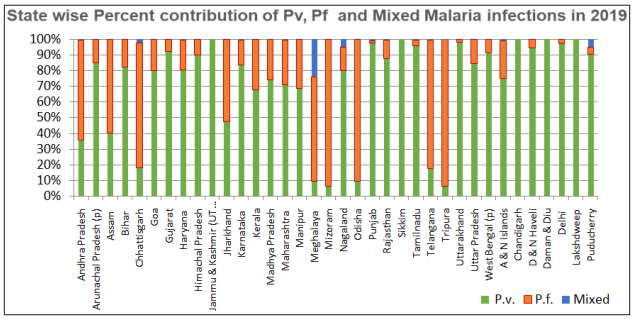


Figure 7.Proportion of *P. falciparum*, *P. vivax* and Mixed Infection in different States/ UTs in 2019

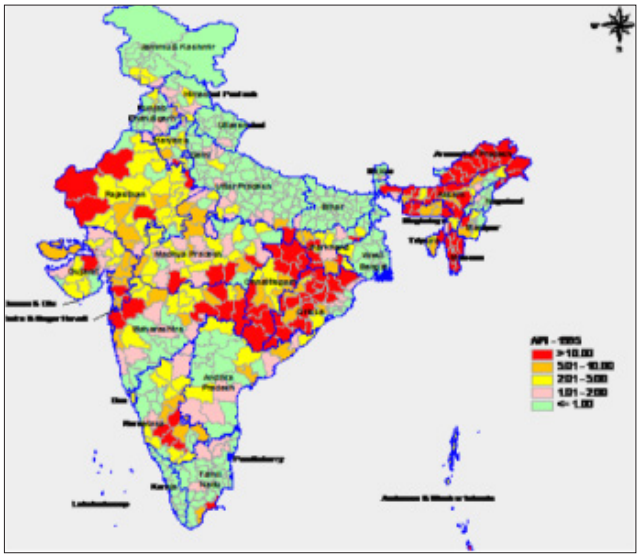
Shrinking Map of Malaria Endemicity

The country has made significant progress in malaria control in recent years. The reported confirmed cases declined by 63% from 1,169,261 in 2015 to 429,928 in 2018. In the same period, malaria deaths were reduced by 75% from 384 to 96. The World Malaria Report 2018 documented a remarkable decline in malaria cases and deaths in India. According to the World Malaria Report 2019, India represented 3% of the global malaria burden. India showed a reduction in estimated malaria cases of 24% in 2017 compared with 2016 and 28% in 2018 compared with 2017.

Figure 8 shows that the map of malaria burden is shrinking in the country and more and more districts have been shifting towards the lower API group since 1995. High burden areas have been significantly reduced. There is a total of 660 reporting districts in the country and 18 other reporting units like corporations, etc., making a total of 678 reporting units. Of the 648 districts, 594 (92%) had an API less than 1/1,000 and only 8 districts had an API greater than 10/1,000 in 2018.

It is an important point to highlight that surveillance (ABER) has also been strengthened as shown in the figure because of a greater involvement of ASHAs at the community level for diagnosis by using RDT and treatment of malaria.

While this progress is highly commendable, the disease is still a major public health problem in many districts in several states.



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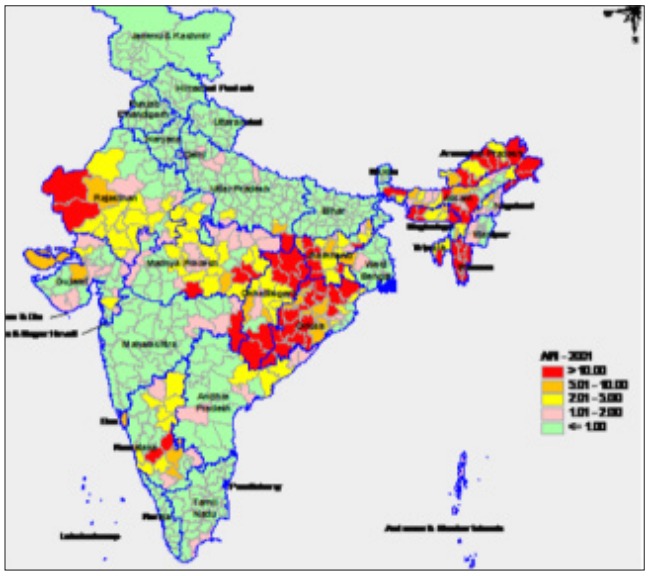

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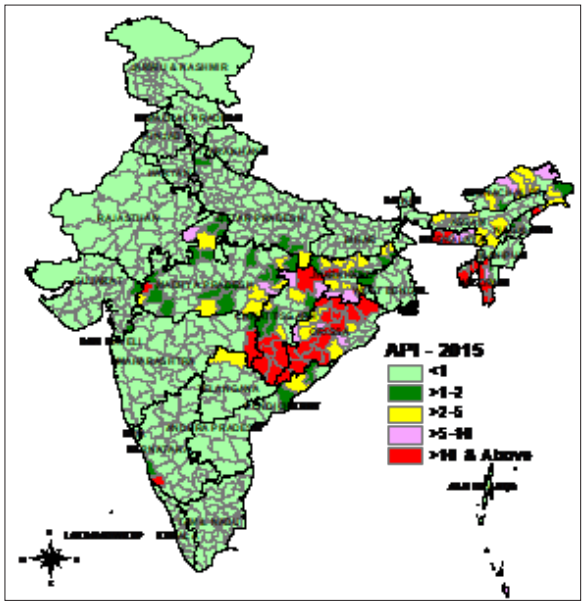

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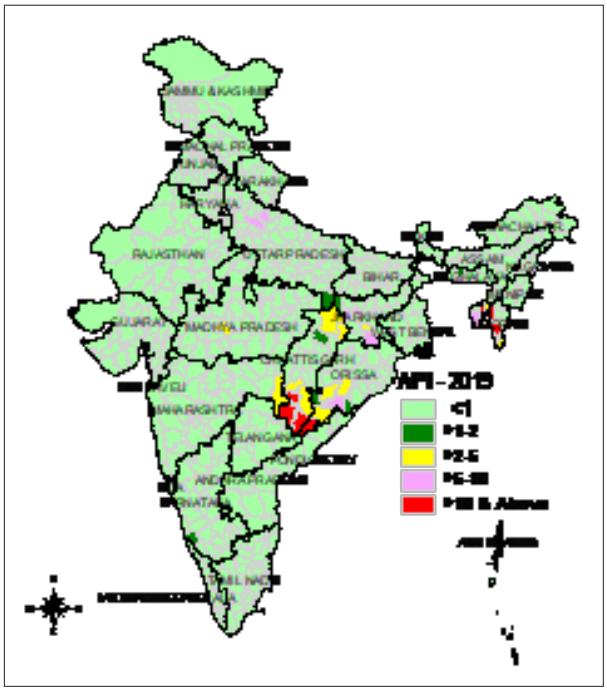

2019

Figure 8.Geographical Distribution of Malaria Endemic Areas based on API showing Shrinkage of Malaria Burden Map in India; 1995, 2001, 2015 and 2019

Moving towards Malaria Elimination

The malaria programme of India has committed to eliminating malaria by 2030 in line with the Global Technical Strategy (2016-2030) and Asia Pacific Leaders Malaria Alliance (APLMA) roadmap. The National Framework for Malaria Elimination (NFME) 2016-2030[2] was launched by the Union Health Minister in February 2016. Malaria elimination will contribute towards the attainment of the sustainable development goals (SDGs) by 2030, especially Goal 3 - "Ensure healthy lives and promote well-being for all at all ages: ending the epidemics of malaria, AIDS, tuberculosis, and neglected tropical diseases".

Strategic Approaches for Malaria Control

India embarked upon a paradigm shift from control to elimination from 2016 onwards. Differential strategies and targeted interventions based on endemicity are being aimed at for continual transitioning of states/ UTs and districts to malaria-free areas and preventing the reintroduction of malaria. The NFME serves as a roadmap for advocating and planning malaria elimination throughout the country in a phased manner across 36 states and union territories (UTs). States/ UTs have been divided into four categories (Table 2) based on Annual Parasite Incidence (API) as the primary criteria, milestones, and targets are set for 2020, 2024, 2027, and 2030.

Table 2.Classification of States/ UTs based on API

Categories of States/ UTs	Definition
Category 0: Prevention of establishment phase	States/ UTs with zero indigenous cases of malaria.
Category 1: Elimination phase (Goa, Haryana, Himachal Pradesh, J&K, Kerala, Manipur, Punjab, Rajasthan, Sikkim, Uttarakhand, Chandigarh, Daman & Diu, Delhi, Lakshadeep, and Puducherry)	States/ UTs (15) including their districts reporting an API of less than 1 case per 1000 population at risk.
Category 2: Pre-elimination phase (AP, Assam, Bihar, Karnataka, Maharashtra, TN, Telangana, UP, WB, Nagaland, and Gujarat)	States/ UTs (11) with an API of less than 1 case per 1000 population at risk, but some of their districts reporting an API of > 1 case per 1000 population at risk or above.
Category 3: Intensified control phase (Arunachal Pradesh, Chhattisgarh, Jharkhand, Madhya Pradesh, Meghalaya, Mizoram, Odisha, Tripura, A & N, and D & NH)	States/ UTs (10) with an API of 1 case per 1000 population at risk or above.

Table 3.Categorisation of Districts in NSP

Category of Districts	Definition	Number (%)
Category 0: Prevention of re-establishment phase	Districts/ Units historically considered to be without local transmission and reporting no case for the last 3 years. Vigilance will be maintained in these districts to prevent the reintroduction of malaria in view of climate change	75 (11.1)
Category 1: Elimination phase	Districts/ Units having API less than 1 per 1000 population	448 (66.0)

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Category 2: Pre-elimination phase	Districts/ Units having API 1 and above, but less than 2 per 1000 population. These are targeted for elimination in the subsequent years.	46 (76.8)
Category 3: Intensified control phase	Districts/ Units having API 2 and above per 1000 population. These are positioned for elimination targeting in the subsequent years.	109 (16.1)

Table 4.Categorisation of Districts as per API India (2015-2019)

Year	Category 0	Category 1	Category 2	Category 3	Total
2017* (NSP)	75	448	46	109	678
2018	126	526	21	42	715
2019	179	497	10	32	718

*As mentioned in NSP-2017-2022

Before it is practicable and rational to investigate each case, malaria incidence in high transmission areas (Category 3) must be reduced first. The goal of this strategy is to eliminate malaria in Category 1 districts (API < 1) by 2020 and Category 2 districts (API 1-2) by 2022, while reducing transmission in Category 3 districts to stabilise API < 1 by 2022. The NSP has clearly articulated the objectives, strategies and time-bound activities directed towards reducing malaria transmission. A detailed categorisation is given in Table 3. In sync with NFME, the National Strategic Action Plan for Malaria Elimination in India 2017-2022 (NSPME)[8] was developed by NVBDCP with the support of WHO Country Office, India, with a focus on district-based planning. NSP 2017-2022 was launched by the Hon'ble Union Health Minister & Family Welfare on 12 July 2017. The districts across all states and UTs (678 districts) have been stratified into four groups based on the average reported API in the last three years 2014-2016 (Table 2).

However, different interventions including long-lasting insecticidal net (LLIN) distribution and indoor residual spray (IRS) continue to be at the sub-centre level (API >1 for LLINs, and API > 2 for IRS) in the districts.

The district-wise classification was done in NSP in 2017; there were 109 districts (16.1%) under intensified Control Phase of category 3, having API above 2, while in 2019, there were only 32 districts in Category 3 (Table 4). There were 75 districts identified in NSP with zero indigenous cases in 2017 and there were 179 such districts showing zero cases reported in 2019. There are challenges in the country to validate these districts with reported zero indigenous cases in Category Zero.

Program Initiatives for Malaria Control/ Elimination in India

India achieved success in the reduction of malaria incidence in the country. This has been made possible by a series of undertaken interventions and the introduction of new tools under the malaria programme in the last decades as given below:

Diagnostic and Treatment: A new dimension in diagnosis and treatment has started in the country with the introduction of artemisinin-based combination therapy (ACT) for treatment of *Plasmodium falciparum* malaria in 2004-05 and the introduction of malaria Rapid Diagnostic Tests (RDTs) for detection of *P. falciparum* cases in 2004-05 and bivalent RDT in 2013. To prevent resistance to ACT, the imposition of a country-wide ban on oral artemisinin monotherapy was done in 2009. The National Malaria Drug Policy of India has been revised in 2013 based on the results of therapeutically efficacy studies (TES) conducted for the monitoring of drug resistance. Research support is being provided by WHO and NVBDCP to the National Institute of Research on Tribal Health and the National Institute of Malaria Research (ICMR) for monitoring anti-malarial drugs in the country as per the WHO protocol. Monitoring of the efficacy of ACT along international borders is also being undertaken.

Quality Assurance System on Malaria Microscopy: Quality Assurance System on malaria microscopy is being strengthened in the country by NVBDCP in collaboration with WHO. NIMR is also supporting NVBDCP to organise refreshers training as well as External Competency Assessment of Malaria Microscope (ECAMM). 30 WHO certified L1 and L2 malaria microscopists are now available in the country as core trainers for cascading training in the states. The training plan for QAMM has been developed and executed. First time, a technician from India, qualified as an external ECA facilitator for ECA and would be used for further quality assurance training.

Surveillance: In recent years, the NVBDCP has introduced the use of bivalent RDTs (Figure 3) to help with the early detection of malaria positive cases. PHCs, malaria clinics, CHCs, and other secondary and tertiary level health institutions that patients attend for treatment, do passive

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malaria surveillance. Apart from that, an important initiative recently introduced by the National Rural Health Mission (currently renamed as 'National Health Mission'-NHM) is the provision of village-based "Accredited Social and Health Activists" (ASHAs), personnel that have been trained in malaria diagnosis by rapid diagnostic tests (RDTs) and antimalarial drug administration services at the community/ village level. The ASHAs are eligible to receive incentives for case detection and treatment completion of malaria cases. Hence, in recent years, diagnosis and treatment have improved.

Malaria Vector Control in India: Implementation of malaria vector control measures in India is broadly based on the API of the area. In India, vector control is a core component of malaria prevention and it involves the use of Long-Lasting Insecticidal Nets (LLINs) and indoor residual spraying. Larval source management (LSM) like larvicides, larvivorous fishes and source reduction are employed as supplementary interventions. As per NSP 2017-22, stratification for vector control activities isrequired to be done up to the sub-centre level which is the unit for Integrated Vector Management (IVM). The category-wise vector control measures recommended are given in NSP 2017-2022.

LLIN is one of the most effective tools for the prevention of malaria to reduce human-vector contact by personal protection. LLINs were introduced in the programme in 2009. However, a significant scale-up in LLIN coverage for the population living in high-risk areas has been achieved during 2015-2019. Till 2019, a total of 49 million LLINs (from GFATM + domestic budget) have been procured and distributed in Madhya Pradesh, NE states, Odisha, Chhattisgarh, and Jharkhand. Some states also continue insecticide impregnation of community-owned bed nets.

In order to achieve the goal of malaria elimination in the country, the programme changed the eligibility criteria for the distribution of LLINs by including SCs having API > 1 (with 1 LLIN per 1.8 persons).

IRS is implemented selectively in high-risk pockets (unit for coverage of IRS in malaria is sub-centre) as per sub-centre (> 2 API) micro plans. Over the years, there is a reduction in the targeted population in view of the decline in malaria endemicity. Biological larval control using larvivorous fish is feasible in certain ecotypes and settings and is propagated as a supportive intervention to control the breeding of mosquitoes. Chemical larvicides and bio-larvicides are being used especially in urban areas.

IHIP Malaria Modules: WHO has supported the government in the development of the malaria modules under the Integrated Health Information Platform (IHIP) to enable near real-time reporting and monitoring of data to guide better programme implementation. IHIP malaria modules are being implemented in two states - Odisha and Himachal Pradesh.

Updating insecticides resistance data of malaria vectors on annual basis in the country is being used for the development of resistance management plans in the country.

Cross Border Meeting: A strategic framework for strengthening cross border collaboration in South Asia has been prepared by WHO and NVBDCP in 2017. Indo Bhutan collaboration meeting was organised in 2019. An action plan for Indo-Bhutan collaboration for malaria elimination has been developed and executed by the neighbouring districts.

Capacity Building: All states and Union Territories were sensitised for NSP 2017-2022 implementation and Training of Trainers (ToT) conducted in collaboration with WHO Country Office India, with the objective of building a pool of trainers across the country for capacity building on malaria elimination. Further cascade training aligned with NSP, is being conducted in the states and UTs. Also, training on Sub-national Malaria elimination is also introduced in the malaria programme.

Programme reviews are regularly done by the programme at regular intervals.

Approaches for Malaria Reduction in High Burden States

High Burden High Impact (HBHI) Approaches: The "High burden to high impact: A targeted response"(HBHI)[14] approach was launched in November 2018 by the World Health Organization and the Roll Back Malaria (RBM) Partnership to End Malaria, as a country-driven response to achieve rapid and sustainable malaria impact. The response is being led by 10 high burden countries of Africa and India. Ten countries in Africa (Burkina Faso, Cameroon, the Democratic Republic of Congo, Ghana, Mali, Mozambique, Niger, Nigeria, Uganda, and the United Republic of Tanzania) have the highest burden of malaria. India is the early adopter of the HBHI approach outside the African countries. HBHI approaches demand high-level political leadership, country ownership, and commitment from a broad coalition of stakeholders. The measures are focused on converting political commitment into concrete actions, improving strategic information usage to create impact, and implementing the best global policies, guidelines, and strategies. The approach is founded on 4 pillars (Figure 7).

According to the World Malaria Report 2019,[5] the two high-burden-to-high-impact (HBHI) countries that achieved a significant reduction in malaria cases in 2018, as compared with the previous year, were India and Uganda.

India's Status of HBHI Approaches

In India, HBHI approaches are adopted and adapted by

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NVBDCP in collaboration with WHO in four high burden states,[15] namely Chhattisgarh, Madhya Pradesh, West Bengal, and Jharkhand. Malaria cases and deaths have significantly decreased in these states. HBHI is a holistic approach, with the 4 elements feeding into tangible actions through NSP implementation and concrete outcomes. The WHO Country Office and NVBDCP organised a meeting of high malaria burden states in India with the participation of WHO HQ, Regional Office and the RBM Partnership to discuss the adaptation of the HBHI approach on 13 & 14 May 2019 in Bhopal, Madhya Pradesh. It was decided in the meeting that initially HBHI would be adopted in four states in the country. WHO has provided intensive support to four states for situation analysis and framing the strategic plans.[15] Each state was supported to develop its state-specific strategic plan and district operational plans. The strategic plan will be based on an in-depth situation analysis in each of the four states using the HBHI approach supported by WHO.

Two training workshops for district level officers and consultants were organised in Chhattisgarh from 13 to 16 November 2019 and in Madhya Pradesh from 2 to 5 December 2019 by WHO in collaboration with NVBDCP.[14] The states were oriented on the HBHI approach, including "Zero Malaria Starts with Me". The training's major goals were to establish context-specific approaches/ plans to expedite malaria burden reduction in each district in the HBHI-affected states.

Malaria Vectors in India

Six Anopheles species, *Anopheles culicifacies, Anopheles fluviatilis, Anopheles baimaii, Anopheles stephensi, Anopheles sundaicus*, and *Anopheles minimum*, have been identified as primary malaria vectors in India. In addition, *Anopheles philippinensis, Anopheles annularis, Anopheles nivipes*, and *Anopheles varuna* are the secondary malaria vectors that transmit malaria along with either one or two major vectors in different regions.[16] *Anopheles culicifacies* and *An. fluviatilis* are the major vectors contributing to 75-80% of malaria cases in India.

The key characteristics of these vectors are summarised below:

- *An. culicifacies* is widespread in peninsular India and is the most dominant malaria vector in the rural and peri-urban areas. *An. culicifacies* alone is responsible for 60-70% of malaria annually.[16,17] It is highly zoophilic as a result of which the presence of a high density of cattle relative to that of humans limits its vectorial capacity
- *An. stephensi*, prefers to breed in artificial/ man-made containers and is mostly responsible for malaria in urban, industrial areas, and in some desert ecotypes[18]
- *An. fluviatilis* is the main vector of malaria occurring in hilly areas, forests, and forest fringe areas in many states. It contributes to about 15% of malaria cases in the forested areas, foothills, and plains[12]
- *An. minimusis* the vector responsible for malaria occurring in the foothills of east and north-eastern states of the country[19]
- *An. dirus* (baimai), an important forest vector in the North-East, is well known for its exophilic behaviour
- *An. epiroticus/ An. sundaicus*, a brackish-water breeder, is restricted to causing malaria in the Union Territory of Andaman & Nicobar Islands.[20,21] It prefers to breed in brackish water.

The diverse malaria epidemiology in India is mirrored by the high diversity of malaria vector species, most of which exist as complexes comprising several cryptic species that vary in vectorial capacity.[16]

Insecticide Resistance

In India, DDT and hexachlorocyclohexane (HCH) were introduced for public health use (vector control) during the 1950s, and malathion was brought in for vector control during the 1960s. In 1997, HCH was banned from public health use and this insecticide is not used for vector control anymore. The use of DDT for indoor residual spraying (IRS) and malathion continues primarily for space spraying in the NVBDCP. Synthetic pyrethroids (SP) have been introduced during the last one and a half decades for IRS and impregnation of mosquito nets. This is the only insecticide group recommended for net treatment. Currently, insecticides of the organochlorine (DDT), organophosphate (malathion), and synthetic pyrethroid (deltamethrin, cyfluthrin, lambda cyhalothrin, alphacypermethrin, permethrin, and bifenthrin) groups are used for the control of vectors in India. Carbamates are not used as they are expensive and possess high mammalian toxicity.

The extensive use of insecticides, particularly DDT, under the vector control programme, controlled malaria to a great extent but exerted high selection pressure on the vector population to develop resistance. Among the six primary vectors of malaria in India, resistance to DDT has been widespread in *An. culicifacies*. Kumari et al.[22] reviewed the susceptibility status of different malaria vectors against different insecticides used for public health in India and first time published an updated map. After that, a review was done by Raghavendra et al.[17] between 1991 and 2016 in 145 districts in 21 states and two union territories. The data indicated that *An. culicifacies* was resistant to at least one insecticide in 70% (101/145) of the districts. Resistant to DDT and malathion is predominant whereas, its resistant status against deltamethrin varied across the districts. The major threat to the malaria control programme is multiple-insecticide-resistance in *An. culicifacies* which

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needs immediate attention for resistance management as this species contributes to about 2/3rd of malaria cases in the country. The routine monitoring of insecticide resistance in malaria vectors is the immediate need of the programme.

Challenges

India contributed only 2% of malaria cases globally (WMR 2020). In SEARO, India (88%) is the highest malaria burden country with the highest *Plasmodium vivax* prevalence. Malaria elimination efforts in the region are expected to be boosted if India's malaria control efforts are successful. Despite significant progress, India faces numerous obstacles to malaria elimination, including diverse patterns of malaria transmission in different parts of the country demanding area-specific control interventions; predominantly forested, tribal and difficult-to-reach areas in malaria-endemic areas; varying degrees of insecticide resistance in vectors and the threat of antimalarial drug resistance. Malaria in high endemic areas poses challenges on account of hard-to-reach areas (forestation, geographic accessibility, climate) and high-risk groups (for example, tribal/ ethnic groups, shifting/ jhum cultivators, migrant and mobile populations, etc.; these key populations are often poor, marginalised, and illiterate). Such factors impede access to timely prevention, diagnosis, and treatment by floating groups, leaving them vulnerable and compromising their human rights to adequate care. Additionally, there is low community awareness of malaria prevention and control among the tribal and marginalised population. Even in states with lower malaria transmission, majority of malaria is confined to pockets having the above-mentioned eco-epidemiological scenario as well as the continuous influx of mobile and migrant populations from neighbouring moderate/ high endemic states and bordering countries.

Lack of real-time disease reporting system, delay in detection of early warning signals, and delayed response are potential challenges with respect to outbreak detection and management system. Being an epidemic-prone disease, real-time reporting of malaria cases from remote and poorly served areas is a challenge. This gap in surveillance may be strengthened by employing a 'village/ community volunteer' in difficult to reach areas which are cut off from the system during the rainy season and are devoid of ASHAs. Thus, for elimination, sustained and more intensive efforts, empowered communities, strengthened health and community systems and enabled environment and resources are necessary; without which there is a possible risk of turning low endemic into high-risk areas.

Furthermore, India's porous borders may provide a possible entry point for artesunate-resistant parasites from Southeast Asia. If we are to reach the goal of malaria elimination in the area, we need to have an urgent conversation about combating malaria across borders - between India's states/ districts and neighbouring countries - through sharing of data, information and coordinated control and prevention measures. Many challenges threaten continued progress, and if left unaddressed, render some of the current tools ineffective and trigger a rise in malaria morbidity and mortality. To avert and delay these challenges, there is an urgency to avail the opportunity to accelerate progress towards elimination.

Mobile Migrant Population

From the control perspective, migration malaria is the most challenging as migrants generally remain out of the ambit of organised health services, are hard to track and monitor, and generally do not comply with the control strategy of the country.[23]

Human populations move for labour work in projects/ construction sites, mining, jhoom cultivation, agriculture, tourism, and natural disasters. In South-East Asia, movements on forest fringes are responsible for 'forest malaria'.[24] There is an urgent need to study population migration patterns in India and their implications on malaria elimination.

Discussion

The two major human malaria species in India are *Plasmodium falciparum* and *Plasmodium vivax*; both are unevenly distributed across India. However, cases of *Plasmodium ovale* and *Plasmodium ovale* have also been reported from some parts of the country.[25-27] Sporadic cases of *Plasmodium ovale* were found in India in hilly forested areas.[28-30]

P. vivax is more prevalent in the plains while *P. falciparum* predominates in forested and peripheral areas. Mixed-species (Pv and Pf) infections are prevalent more in Chhattisgarh, Meghalaya, Nagaland, and Puducherry (Figure 5) in 2019. However, Das et al. reported that mixed infection was found more in Gujarat. During 2018 and 2019, in total, 53.6 and 51.81% of *P. vivax* and 45.7 and 48.19% of *P. falciparum* malaria respectively, were reported in the country. The proportion of cases attributed to *P. falciparum* remained around 50% from 2000 to 2013, but rose to 65.6% in 2014 and 67.1% in 2015, possibly due to increased *P. falciparum* detection through the widespread use of RDTs introduced in 2013 by trained ASHAs. *P. vivax* is a predominant species in category 1-low endemic states. Since it is a challenge to follow 14 days of radical treatment in such places, so focussed attention should be given to eliminate vivax parasite completely to achieve the goal of malaria elimination. Globally, 53% of the *P. vivax* burden is on the WHO South-East Asia Region, with the majority being in India (47%) in 2018 (WMR 2019) while in 2017, it was 48%.

In 2019, 88.7% of Pf cases were contributed from six states -

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Chhattisgarh, Odisha, Jharkhand, Uttar Pradesh, Tripura, and Mizoram (Figure 6). A high proportion of *P. falciparum* (up to 90%) is seen in zones inhabited by ethnic tribes in forest ecosystems where stable malaria conditions occur (State NVBDCP report). Most of these areas are in category III of malaria high burden states. The state of Chhattisgarh is also inhabited by ethnic tribes mainly in the forest ecosystems; meso- to hyper-endemic conditions of malaria existed with the preponderance of *P. falciparum* in 2018 and 2019. Bastar division contributed the highest proportion of malaria in the state, therefore the state has also initiated mass screening and treatment in hardcore areas in the state and target to achieve malaria elimination in Bastar. However, Odisha contributed 55.47% of Pf cases in the country in 2017 which reduced to 23.1% in 2019.

There is very limited information on the age and gender-specific prevalence of malaria in India. In the available studies, age and gender classification used is arbitrary.[31-33] The malaria burden is mostly higher in males than females in all age groups. These studies showed that children in states like Assam, Arunachal Pradesh, and Rajasthan had a higher incidence of malaria than adults, whereas, in the Indo-Gangetic plains, the situation was reverse.

In India, malaria is concentrated mostly in tribal, forest associated, and marginalised populations, and places where it is difficult to implement timely prevention and early diagnosis and treatment. During the last decade, the states of Orissa, Jharkhand, West Bengal, North-eastern states, Chhattisgarh, and Madhya Pradesh contributed the bulk of malaria.[34] About half of Pf cases (54.1%) were contributed by Odisha and Chhattisgarh. These states have large forested, hilly, inaccessible areas, and significant tribal populations. Sharma et al.[8] also reported that in India, malaria is a major problem in tribal areas and the neglect of the ethnic communities in tribal areas would be detrimental to the overall reduction of morbidity and mortality due to malaria in the country. These states/ districts are dominated by tribal populations, are forested areas, hard to reach and are intersected by numerous streams and water-logging which support mosquito breeding throughout the year.[8,35,36] Moreover, ethnic communities prefer to go to spiritual healers for treatment,[37,38] or to untrained and unlicensed practitioners (quacks).[37-41] Hence these tribal-dominated states/ UTs and districts need special attention. Adoption of HBHI approaches in these districts and socio-economic development of the tribal communities would definitely reduce the malaria burden.

However, in recent years, malaria cases have declined in high burden states too. Odisha was the highest malaria burden state in 2016; 40% of malaria cases were contributed only by this state until 2017.[7,42] Its remote, heavily-forested regions with scattered tribal populations were the most vulnerable to high malaria. However, since 2016, cases and deaths are declined drastically; there was a 91% decline in malaria cases in 2019 compared to 2016 in Odisha and it is the third-highest burden state in the country. The reported malaria cases drastically declined (60.9%) in Odisha from 347,860 in 2017 to 66311 in 2018 and deaths dropped from 24 to 3, according to reported data. During mid-2017, 11.13 million LLINs which were supplied through the Government of India by the Global Fund were distributed as well as DAMAN was operationalised (elimination of malaria in inaccessible regions). DAMAN was conceived in 2016 but it became operational in mid-2017[43] in the eight most high-burden districts. Routine surveillance, case diagnosis and treatment through the network of around 47,000 ASHAs and health facilities from district to sub-centre levels continued in addition to vector control by IRS. Similar progress has been made in the north-eastern states, where 7.2 million bed nets were distributed in late 2015 and 2016. Between 2016 and 2017, the reported number of cases of malaria fell from about 165000 to fewer than 37000, according to government figures (https://www.who.int/malaria/news/2018/india-elimination-odisha/en/). Besides bed nets, increasing efforts are being made to expand the use of rapid diagnostic tests involving ASHA and to provide early treatment for positive cases and continue indoor residual spraying as per government policy. Community health volunteers are also deputed in hard to reach areas, but still, it is a matter of concern in many difficult-to-reach villages in North-Eastern states, Chhattisgarh, Jharkhand, Odisha, and other parts of the country, which are often cut-off from the routine reporting system due to lack of communication (e.g. no roads, forest villages, conflict-affected etc.). Tribal population, mobile and migrant population, and jhoom cultivators are often deprived of access to preventive, promotive and curative care. In order to strengthen overall surveillance, such areas/ villages may be identified and 'Village/ Community Volunteers' may be trained for routine reporting.

India contributes about 88% of the malaria burden in Southeast Asia (WMR, 2020). Thus, in the region, there is a critical need to reduce the burden in India in order to progress towards malaria elimination, although, India has made significant progress in malaria control in recent years. The reported confirmed cases declined by 71.05% from 1,169,261 in 2015 to 338515 in 2019.In the same period, malaria deaths were reduced by 79.95% from 384 to 77 in 2019 as per NVBDCP reported data. World Malaria Report also recorded a 24% reduction in estimated cases in 2017 compared to 2016 and a 28% reduction inestimated cases in 2018 compared to 2017. Globally, India reported the largest absolute reductions in cases, in 2019 (WMR 2020). India is no longer among the top three countries with the highest malaria burden as reported in WMR 2017 and its

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position is down at the eleventh in the world in WMR 2019 and further down in WMR 2020.

The success of a drastic reduction of malaria incidence in the country might be due to the scale-up of vector control interventions (LLINs), the use of bivalent RDTs to help facilitate early detection and involvement of community (ASHA) for diagnosis and treatment. A significant scale-up in LLIN coverage for the population living in high burden areas has been achieved during 2015-2019 and about 49 million LLINs have been distributed in high burden states. Malaria control programme has been moved away from "ONE size fit to All" approaches to achieve malaria elimination in a phased manner in different states/ districts. Case-based surveillance is being strengthened in low burden areas. India has adopted a strategic approach for malaria elimination in the country in a phased manner which would help in meeting the goals of NMEF and NSP 2017-2022. NVBDCP has also adopted HBHI approaches in four high burden states in collaboration with WHO.

Despite remarkable gains, there are many challenges to malaria elimination in India, including varied patterns of malaria transmission in different areas,varying degrees of insecticide resistance of vectors and antimalarial drug resistance, and vacancies of entomologists and front line workers for the programme in the states/ UTs, scale-up real-time reporting and strengthening surveillance. Involvement of on case diagnosis and treatment, role of ASHA is very important in the country but there is also a challenge to train all 1287000 ASHA (NSP2017-22). In tribal areas, because of poor writing skills, they may require a pictorial-based reporting system.

Case-based surveillance needs to be strengthened in low endemic areas while universal coverage of core vector control interventions needs to be done in high burden states. Additionally, the acceptability of IRS is also a concern like households not wanting to spray in parts of houses such as kitchens where food is stored or rooms with altars (53-Sundararajan et al. 2013) so awareness needs to be strengthened of how IRS helps in protection from vector bites. Insecticide-resistant mosquitoes were one of the main hurdles faced by the ultimately unsuccessful Global Malaria Eradication plan in the middle of the last century,[44-47] and present-day experience reconfirms this experience. So a good insecticide resistance management plan needs to be developed.

Vector surveillance will play an important role to sustain the malaria elimination process, even in the areas with zero indigenous cases. As it has been seen in Sri Lanka, the invasion of *An. stephensi* in some urban cities in the post-elimination era is a warning signal.[47]

As the programme uses one class of insecticide-synthetic pyrethroids, used in IRS and LLINs, sooner or later the species will develop widespread resistance to pyrethroids. Thus, for effective control of malaria vectors, Insecticides Resistance Management Plan (IRMP) aligned with the GPIRM needs to be developed and implemented in the country. As per WHO Guidelines for malaria vector control (WHO, 2019), there is limited evidence that combining IRS with LLINs in areas of high LLIN coverage reduces the malaria burden. It should only be combined when managing insecticide resistance using a non-pyrethroid for IRS. The best practice is that the Control programme should deliver either IRS or LLINs at high coverage and high quality and not as a means to compensate for the deficiencies of the primary intervention. Programmes that are currently implementing both in the same areas should evaluate the effectiveness of the two interventions.

During the years 2017, 2018 and 2019, India achieved a drastic reduction inboth cases and deaths (Figures 1 and 5). To sustain the progress made so far and further scale-up interventions to achieve malaria elimination, capacity building of all health personnel across the country is required. Foci investigation and response plans should be made an integral part of the malaria elimination plan to achieve the target for sub-national malaria elimination. Excellent surveillance and response are keys to achieving and maintaining malaria elimination. Case and foci-based malaria surveillance in the country starting from Category 1 states would also progressively be made functional.

The COVID-19 epidemic is putting the world's most resilient health systems to the test. In the context of the COVID-19 pandemic, WHO asks countries to guarantee the continuation of essential malaria services. WHO has provided Operational guidance for countries for maintaining essential health services in the context of the COVID-19 response and guidelines for "Tailoring malaria interventions in the COVID-19 response" (GMP WHO, 2020). Ensuring access to core malaria prevention measures is an important strategy for reducing the strain on health systems; these include vector control measures, such as LLINs and indoor residual spraying. Timely diagnosis of malaria and treatment are also important to be continued, ensuring the safety of communities and health workers. NVBDCP emphasises the critical importance of sustaining efforts to prevent, detect, and treat malaria. The programme is emphasising states to continue diagnosis and encourage ASHA to test malaria preferably by using RDTs, even during national lockdown from 22 March to 1 May 2020. Although malaria incidences have decreased in 2020, it may be due to a decrease in surveillance or reduced exposure for man mosquito contact due to less mobility of people. After lockdown, LLINs mass distribution and IRS as per programme policy are also continued for prevention and

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control of malaria in the states during COVID-19 pandemic by maintaining the safety of health workers. In view of the ongoing COVID-19 pandemic, there is a need to ensure that the gains achieved so painstakingly in the malaria programme are not squandered and malaria outbreaks could be prevented in the forthcoming season.

Conclusion

In the past, a series of setbacks were witnessed leading to malaria resurgence in multiple foci in the country after achieving tremendous success in moving towards eradication. The failure was accredited to complacency, as well as administrative, operational, and technological issues such as DDT resistance in vectors and chloroquine resistance in parasites. In recent years, a remarkable reduction in malaria incidence is achieved so painstakingly; thus, there is a big challenge for the programme to retain the goals achieved so far. There is also a challenge to continue essential services for test and treatment and for implementation of interventions for prevention and control/ elimination of malaria during COVID-19 pandemic. Efforts need to be accelerated on war footing to strengthen surveillance throughout the country along with real-time reporting, capacity building to all levels of health functionaries, situation analysis for appropriate planning and implementation of strategic plans. There is also a need to act in time by developing tools for early warning signals for the outbreak and appropriate plans for public health interventions.

Malaria elimination is not possible to achieve without strengthening case and foci-based surveillance in low endemic areas. Foci-based control interventions are recommended in low endemic settings where case investigations are done. Focus investigation and response plan should be an integral part of the malaria elimination plan. In inaccessible hard-core areas, community participation is important so the involvement of social workers and NGOs at the right levels would solve the problem of community participation to an extent.

India's progress is well appreciated globally, but there is an opportunity for the country to accelerate further malaria elimination activities at the district and peripheral levels to achieve the target goal of malaria elimination. There is a need to get more vigilance and appropriate planning to accelerate malaria elimination activities more carefully.

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Abbreviations

API: Annual Parasite Incidence per thousand; IRS: indoor residual spraying; ITNs: insecticide treated nets; LLINs: long lasting insecticide nets; MPO: modified plan of operation; NVBDCP: National Vector Borne Disease Control Programme; Pf: *Plasmodium falciparum*; Pv: *Plasmodium vivax*; RDT: rapid diagnostic test; SP: synthetic pyrethroids; SPR: slide positivity rate, ACD: Active Case Detection.

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