The Pharma Innovation Journal 2019; 8(5): 803-809

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(5): 803-809
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www.thepharmajournal.com
Received: 26-03-2019
Accepted: 29-04-2019

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Tribal malaria: A challenge to achieve malaria elimination from India by 2030

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Abstract
In India, approximately 1.5 million cases of malaria and about 1000 deaths are reported annually. According to WHO (WHO, 2018), India has recorded nearly 25% decline in malaria cases within 2016 to 2017. However, India's seemingly achievable target of malaria elimination by the year 2030 has so far proved to be a challenging road, particularly in the tribal areas, which are mostly inaccessible forested areas in the plain, hilly and mountainous terrain. Tribal people constitute approximately 8.6% of the population but contribute a substantial malaria burden of the country. The high incidence of *Plasmodium falciparum*infection in the tribal people of some areas is a matter of great concern. Global warming is likely to reshape the ecology of many vector mosquitoes in tribal areas and will have wide ranging consequences on the ecology and epidemiology of malaria. Insecticide resistance to vectors, drug resistance to *P. falciparum*, various socio-economic factors are creating a complex malariogenic and mosquitogenic situations in the tribal areas. Moreover India is surrounded by malaria endemic countries like Bangladesh, Bhutan, Nepal, Myanmar and Pakistan. In India most of the international border areas are porous in nature and not under the ambit of any epidemiological surveillance. A comprehensive eco-epidemiological study encompassing various tribal dominated regions of the country is required to formulate aninclusive policy and area-wise strategy for the elimination of tribal malaria.

Keywords: malaria elimination, tribal malaria, tribal socio-economy, climate change, international cooperation

1. Introduction
Malaria is causing serious public health hazards in different parts of the developing world including India. India accounts for 89% malaria cases in South East Asia. In 2016 total confirmed malaria cases in South East Asia Region (SEAR) member countries of World Health Organization (SEAR-WHO) were 1.4 million and the reported malaria deaths were 557 (WHO, 2017)[53]. The National Vector Borne Disease Control Programme (NVBDCP) of India has developed a comprehensive model to achieve the overarching vision of "Malaria-free India by 2030" (Rahi *et al*., 2019) [20]. In 2017, 0.84 million cases of malaria have been reported from India, a 24% decrease over the previous year. In recent times, the malaria map shows shrinkage in distribution and confinement to some states like Orissa, Chhattisgarh, Maharashtra, and Madhya Pradesh among others is seen (WHO, 2018) [52] which incidentally also have major share of tribal population of the country.The burden of malaria differs in different parts of India as malaria is a focal disease influenced by local ecological and socio-economic factors. Every malarious area has its own ecology and malaria dynamics varies from place to place. Climatic factors have a profound influence on the vectors and parasites (Chattapadhyay *et al*., 2004 and Bhattacharya, 2009) [11, 7]. The epidemiology of malaria is complex owing to geo-ecological diversity, multi-ethnicity and wide distribution of major malarial vectors. Anopheline vectors transmitting four human malaria parasites, amongst them two *Plasmodium* species are predominant in India *viz*., *Plasmodium vivax* and *P. falciparum* with some sporadic cases of *Plasmodium malariae.* Almost half the malaria risk is estimated to occur among people living in forested areas worldwide and is influenced by local factors associated with malaria transmission (Kar *et al*., 2014) [21]. It is fascinating that tribals in India constitute 104.28 million, as per 2011 census, which is about 8.61% of the total population. The state-wise distribution of tribal population in India showed that more than 80% of country's tribal population resides in 11 states *viz*. Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Jharkhand, Chhattisgarh, Andhra Pradesh, Telengana, West Bengal and Karnataka. Over 80% of the country's total malaria cases were reported mostly from these above mentioned states.

Asymptomatic malaria and the migration of nomadic tribal groups having asymptomatic parasitemia are creating a complex malariogenic situation. This may pose a threat to malaria dissemination in hitherto malaria unaffected areas. The five-year National Strategic Plan for malaria elimination launched by India in 2017 has shifted the focus from malaria "control to elimination" (Rahi *et al*., 2019) [20]. However, India's target to eliminate malaria by 2030 initially appears to be achievable but the route towards elimination has proven to be difficult, particularly in the tribal areas, which are mostly inaccessible, inhospitable forested areas in the plains, hilly and mountainous terrains. Considering tribal malaria being a major problem in India, this paper focuses on challenges of tribal malaria in achieving the elimination of malaria by 2030.

2. Socio-economic scenario of tribe dominated areas in India

Tribes with distinct genetic traits, socio-cultural beliefs and practices that greatly influence malaria transmission dynamics are harboured in forests (Kar *et al*., 2014) [21]. Tribal people constitute approximately 8.6% of the Indian population. Ethnic tribes living in the forested pockets of the states like Orissa, Jharkhand, Madhya Pradesh, Chhattisgarh and the North Eastern states which contribute bulk of morbidity and mortality due to malaria are the high burden population (Dash *et al*., 2008) [15]. These groups are marginalized and generally detached from the national mainstream and rarely have access to health service (Louis P., 2000) [26]. Tribal population in India mostly resides in remote areas and it is difficult to reach such places due to forest, hills, valleys, rivers and perennial streams. Improper sanitation, lack of personal hygiene and improper health education are the main factors responsible for tribal diseases such as malaria. Facilities of proper health service in these areas are poor and uneducated tribal people are generally superstitious with their own conservative health beliefs. In Western Orissa, tribal people prefer 'traditional healer' or 'faith healer' or Quacks instead of any medical professional (Pradhan *et al*., 2018) [36]. Primary causes of tribal health problems are economic backwardness and insecure livelihood (Basu, 2000) [4]. Migration for variety of reason is age old practice in tribal groups and according to national census 2001, 30% of the tribal population were migrants in India. With nomadic lifestyle of certain tribes it is difficult to educate them about hygiene and sanitation in a proper way. Migration of malaria infected tribal people may also facilitate the spread of malaria from one place to another. The migrants from rural areas brought in malaria parasites and transmission takes place via local *Anopheles* vectors, *viz. Anopheles stephensi*in urban and *Anopheles culicifacies*in the peri-urban settings, where migrants usually reside in temporary hutments (Kumar, 2019) [37]. The problem of persistent malaria transmission enhances and gets further complicated due to asymptotic malaria cases which are entrenched in low-socioeconomic groupings living in forest-fringe communities, particularly wherein healthcare infrastructure is meager or even non-existent (Dhiman *et al*., 2018 and Chourasia *et al*., 2017) [18, 12]. Asymptomatic carriers become a reservoir for parasite easily as they do not seek treatment for infection (Ganguly *et al*., 2013) [19] and the number of asymptomatic *P. falciparum* malaria cases is significant among tribes (Chourasia *et al*., 2017) [12]. Prevalence of asymptomatic malaria in tribal population of Chhattisgarh was found to be 20 and 22.8% while overall prevalence was 27.6 and 27.7% in the years 2013 and 2014, respectively (Chourasia *et al*., 2017) [12]. Malnutrition among tribes indirectly helps diseases such as malaria to infect the host easily due to their low immunological profile. Considering the currenttribal scenario, their health problems need special attention and proper treatment (Basu, 2000) [4].

3. Materials and Method

3.1 Data Source

The data of malaria incidence (2014-2017) was collected from National Vector Borne Disease Control Programme (NVBDCP) website (www.nvbdcp.gov.in, accessed on 3rd December 2018).

3.2 Statistical analysis

R.A. Fisher and F. Yates, *Statistical Tables for Biological, Agricultural and Medical Research (Table-III) 6th edition, 1963* published by Oliver and Boyd, Edinburgh.

4. Results

Table 1: Year wise incidence of malaria in some tribe dominated states of India

	Total malaria cases				*P. falciparum* cases				Other malaria cases			
Year	**2014**	**2015**	**2016**	**2017**	**2014**	**2015**	**2016**	**2017**	**2014**	**2015**	**2016**	**2017**
Orissa	395035	436850	444843	347860	342280	369533	384668	293718	52755	67317	60175	54142
Madhya Pradesh	96879	100597	69106	47541	41638	39125	22304	16169	55241	61472	46802	31372
Chhattisgarh	128993	144886	148220	140727	108874	123839	121503	114512	20119	21047	26717	26215
Maharashtra	53385	56603	23983	17710	25770	31139	7815	5629	27615	25464	16168	12081
West Bengal	26484	24208	35236	31265	4981	5775	5928	4952	21503	18433	29308	26313

Incidences of malaria in different states of India including tribe dominated areas

The comparative analysis of malaria cases from five tribe dominated states (Orissa, Madhya Pradesh, Maharashtra, West Bengal and Chhattisgarh) of India shows different types of malaria parasite infection.

Table 2: Total incidence of malaria in some tribe dominated states of India

Malaria cases within 4 years →	Total malaria reported	*P. falciparum* cases	Other malaria cases
Orissa	1624588	1390199	234389
Madhya Pradesh	314123	119236	194887
Chhattisgarh	562826	468728	94098
Maharashtra	151681	70353	*81328*
West Bengal	117193	21636	95557

In Orissa the incidence of malaria is highest amongst the five states, having a total of 1624588 reported cases in these four years. Number of *P. falciparum* cases was 1390199. The overall number of infections recorded in Orissa was found to increase till 2016, but in the year 2017 a significant decline was visible. *P. falciparum* infection is however also decreased in number (Figure-2). *P. vivax* had moderate fluctuations in their proportion without any impressive decline, but in Orissa *P. falciparum* malaria was predominant throughout the time of survey.

West Bengal, not a tribe dominated state, but having tribal population in certain rural and forest pockets. Total number of malaria cases was found to be 117193.*P.vivax* is behind most of the malaria infections in West Bengal with a total number of 95557 cases. The overall rate of malaria had increased in 2017, but the proportion of *P. falciparum* infection declined in West Bengal. However, the data indicates that West Bengal was not dominated by *P. falciparum* at any point of time during this study period.

Chhattisgarh was reported with 468728 cases of *P. falciparum* infection in a total number of 562826 malaria cases. The dominance of *P. falciparum* during the study is clearly visible in Chhattisgarh. The number of *P. falciparum* infections is lesser in comparison to Orissa, but contribute a formidable amount of malaria burden to the country. As compared to other states the rate of *P. falciparum* malaria did not have a significant difference with other malaria infections *(P. vivax* malaria) in Maharashtra. The total number of *P. falciparum* and other malaria cases were 70353 and 81328 respectively.

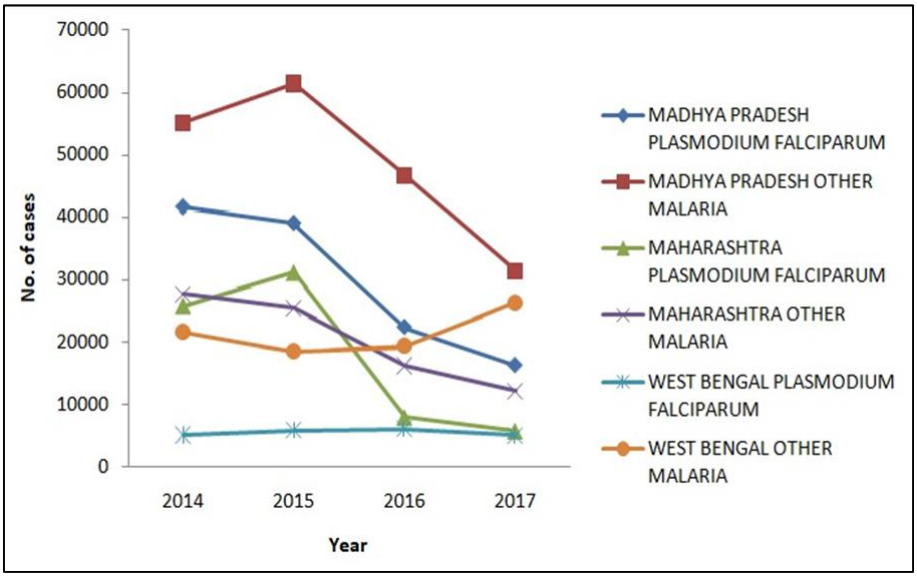

Fig 1: Graphical representation of *P. vivax* dominance in three states of India (2014-2017)

In 2015, *P. falciparum* was found to be predominant in Maharashtra in respect to overall malaria cases. However, in 2016 and 2017, a moderate decline in the total number of *P. falciparum* cases (Figure-1) was evident.

No significant difference had been observed between the *P. falciparum* cases and *P. vivax* cases in Madhya Pradesh. Total estimated malaria count based on the data pooled from 2014 to 2017 is 314123 cases. The overall malaria cases were declined in 2016 and 2017, but the decline of *P. vivax* cases was more significant.

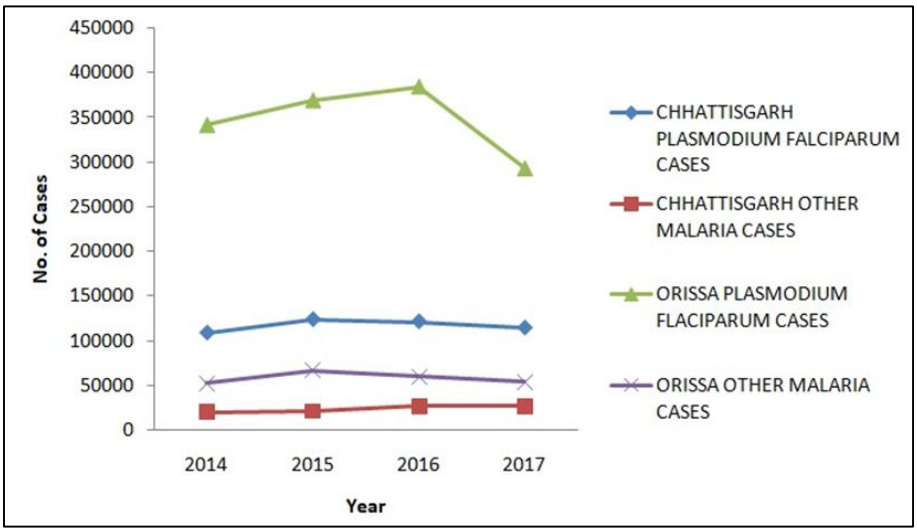

Fig 2: Graphical representation of *P. falciparum* malaria dominance in two states of India (2014-2017).

There is a significant difference between the numbers of *P. falciparum* and *P. vivax* infections were found when compared using statistical methods. The calculated $t_{(0.05)}$ =44.953 (SD= 43096.5, SE=30473.8) is much higher than the

critical $t_{(0.05)}$ =2.447 at 5% significance level. This signifies the difference among numbers of cases in the above mentioned study areas. The distribution of malaria parasites is uneven with certain variations in numbers of cases during the study in some states.

5. Mosquito vector situation in tribe dominated areas

Mosquito fauna in India is rich because of the tropical climate with numerous breeding resources. Depending on forest locality variation in mosquito vectors are found and their behavior changes with the forest micro-climate (Trung *et al*., 2005) [49], human population and social engagements of them (Walker *et al*., 2013 and Alias *et al*., 2014) [51, 1]. Only ten anopheline species are found to be vector of malaria in India (Raghavendra *et al*., 2017) [38]. The primary vectors of malaria are *An. Culicifacies* in peri urban setting and *An. Stephensi* in urban setup (Kumar, 2019) [37]. Besides these two major vectors in India, the other primary vectors are *Anopheles fluviatilis* (in the foothills), *Anopheles minimus* (foothills of Himalayas), *Anopheles dirus*and *Anopheles baimaii* (in the northeastern states) and *Anopheles sundaicus*(in the Andamans) (Kumar, 2019) [37]. There are four secondary vectors except these, namely *Anopheles annularis, Anopheles philippinensis, Anopheles jeyporiensis* and *Anophelesvaruna* (Dash *et al*., 2008) [15]. *An. Culicifacies* and *An. fluviatilis* are the most dominant mosquito species responsible for the transmission of malaria parasites in India, contributing ~65% of new cases annually in rural areas and ~15% in the forested, foothills and plains respectively (Sharma, 1996)[46]. In addition to these, recent reports suggest *Anopheles subpictus* as a potential malaria vector in Indian Subcontinent (Chandra *et al*., 2010) [10]. Poor tribal people are vulnerable to mosquito bites as they mostly sleep outdoors with inadequate clothing and personal protection. Amongst the various malaria vectors in Odisha *An. culicifacies, An. fluviatilis and An. annularis* are found to be very potential and are prevalent in tribal areas. Several anophelines previously considered as belonging to a single species are in fact complexes of various sibling species. Each of the sibling species has its own ecology and behavioral characteristics and plays a different role in the transmission of malaria (Bhattacharya, 2005) [6]. Such types of sibling species are also prevalent in the state of Orissa. *An. culicifacies* is the dominant malaria vector species supported by *An. fluviatilis* in the hilly forested regions of Chhattisgarh (Bhatt *et al*., 2012) [31]. Prevalence of sibling species of *An. Fluviatilis* and *An.culicifacies* complexes are found in Bastar district of Chhattisgarh during entomological studies (Nanda *et al*., 2012) [21]. In Maharashtra the transmission dynamics of malaria is the output of multiple species like *An. culicifacies* and *An. fluviatilis*. Different vector species or sympatric sibling species with fluctuating population according to seasons may be present in a particular region of forest (Obsomer *et al*., 2007 and Baimai *et al*., 1988) [34, 3].

Table 3: Bio-ecology of major Malaria vectors in Orissa

Anopheles species and their complexes	Resting and feeding habits	Breeding habits
An. Minimus Anopheles harrisoni and E	Rests in house and cattle sheds, mostly at lower segment of walls. Highly anthropophilic, exophilic in nature and exophagic food habit.	Slow flowing streams with grassy margins, swamps, shallow wells etc.
An. Culicifacies ABCDE	Mostly rests in cattle sheds and human dwelling. Highly zoophilic, higher density feeds on human	Borrow pits, irrigation channels, seepages, rainwater pools etc.
An. Annularis A/B	Outdoor resting is small, indoor resting in houses, cattle sheds. Mostly zoophilic	Still water with vegetations, wells, burrow pits etc.
An. Fluviatilis STU/V	Cattle huts, Human dwellings, Highly anthropophilic, exophilic and exophagic.	Slow streams, irrigation canals, occasionally rice fields etc.
An. Stephensi Anopheles my sorensis	Indoor resting on hanging objects, behind curtains etc. Outdoor resting in wells, tanks. Feeder of animal and human blood.	Well, tanks, cisterns, rain water, peridomestic containers etc.
An. varuna	Rests indoor in cattle sheds, human dwelling, and mixed; outdoors near stream banks, zoophilic.	Rain water pools, tanks, rice fields, drains, wells, slow moving streams etc.

(***Source*:** Bionomics of malaria vectors in India, Operational Manual for Implementation of Malaria Programme 2009 by Directorate of NVBDCP, Sahu *et al*., 2011 and Dhangadamajhi *et al*. 2015.) [17]

Vector heterogeneity is extensive in Madhya Pradesh where at least three anopheline species are implicated as potential vectors of malaria. The common vector species of Madhya Pradesh are *An. culicifacies* Giles and *An. Fluviatilis* James (Subbarao *et al*., 1992 and Singh *et al*., 2000) [48]. These vectors are species complexes belong to subgenus Cellia and Series Myzomyia and together transmit about 80% of malaria in the country (Subbarao, 1988) [47]. An. culicifacies which is mainly endophilic but in dense forests, it is reported mainly exophilic in nature (Vatandoost *et al*., 2011 and Singh *et al*., 1996) [41, 50]. The possible role of *An. sundaicus*as vector of human *P. knowlesi*has been indicated in recent reports which need to be confirmed (Ghosh and Rahi, 2019) [20].

6. Discussion

Historically, malaria is a rural disease and in general linked with poverty. However, with the passage of time malaria has now assumed significance by becoming disease of economic development associated with peoples various social cultural and economic needs and unsustainable lifestyle (Bhattacharya, 2009, Bhattacharya, 2012) [8, 9]. Likewise various ecotypes of malaria based on its habitation uniqueness has developed such as – rural malaria, urban malaria, forest malaria, migration malaria, irrigation malaria etc. Two human malaria parasites, *P. vivax* and *P. falciparum* are predominant in the country. In most of the hilly and tribal high density areas *P. falciparum* is predominantly present with limited *P. malariae* cases (Ghosh and Rahi, 2019) [20]. However, the number of *P. vivax* is also significant in some states and the unique biology of *P. vivax* with features such as the latent hypnozoite stage (Krotoski *et al*., 1982) [23] and early gametocytogenesis (Mueller *et al*., 2009) [30] making it more difficult to control and eliminate than *P. falciparum.* With this tendency of resurgence *P. vivax* demands special attention in the forest pockets among tribes as the poor people fails to report the incidences most of the time and carries latent hypnozoite stages of parasite in them, creating a possibility for post elimination outbreak.

74.1% of the total malaria cases reported in the country are from tribal dominated states such as Orissa, Chhattisgarh, Madhya Pradesh and Jharkhand (NVBDC, 2017). The climate of these states also favors the malaria condition as tribal villages are intersected by numerous hilly streams and their tributaries which support mosquito breeding throughout the year (Singh *et al*., 1996, Singh *et al*,. 1999, Singh *et al*,. 2013)[46, 42, 45]. However, malaria is a climate sensitive disease and its distribution in different geographic areas related with the temperature, rainfall pattern and relative humidity (Rubio-Palis and Zimmerman, 1997, Minakawa et., 2002, Koenraadt *et al*., 2004 and Aragao MB 1960) [39, 28, 22, 2] along with tree canopy (Zhou *et al*., 2007) [55], flora, fauna (Manda *et al*., 2007) [27], organic content in breeding pool (Okech *et al*., 2007) [35]. Climate change can affect the ecology of mosquito vector as well as the parasite. Earlier, *P. vivax* has been the major infecting species but since the last couple of decades the ratio of *P. falciparum* versus *P. vivax* malaria was 0.41 in 1985, gradually increasing to 0.60 by 1995, and shifting to 1.01 by 2010. Studies show that *P. falciparum* and *P. vivax* are unevenly distributed across India and both the species are transmitted by the same vectors (Singh *et al*., 2004 and Das *et al*., 2012) [43, 12]. In tribal areas the distribution of two major malaria parasites are uneven in present scenario (Table- 1). Climate change along with interspecific competition for niche occupancy among parasites can result in a threat towards eliminating malaria as application of proper measures is difficult in this situation.

Moreover, drug resistant malaria has posed a major problem in malaria control. Artemisinins, an important class of antimalarial medication has encountered early treatment failure owing to artemisinin resistance and late treatment failure due to partner-drug resistance, which emphasize the need for increased surveillance of drug resistance in order to manage the spread of resistant parasites (Yeung *et al*., 2004 and Das *et al*., 2018) [14]. Human migration, being one of the prime causes of spreading drug resistant and virulent strains (Kumar, 2019) [37]. Structure of native population can be affected permanently or temporarily by migration i.e. an age old practices in some ethnic tribal groups. Temporary migration is a bigger issue in this context as the communities of nomads and tribe who are constantly on the move may constitute a reservoir of malaria infection and, therefore, pose a threat to malaria elimination effort (Kumar, 2019) [37]. There is no political boundary to which parasite and mosquito vectors restrict their activities. India is surrounded by malaria endemic countries like Bangladesh, Nepal, Myanmar and Pakistan. In India most of the international border areas are porous in nature and not under the ambit of any epidemiological surveillance and it creates a possibility of malaria re-introduction at post elimination stage especially in areas where the environment favors for quick adaptation of both vectors and parasites. Naturally this aspect can be a matter of concern as migrant human malaria carriers and vectors have resulted in malaria out-breaks in certain places in past (Louis, 2000, Kumar *et al*., 1992 and Dayanand *et al*., 2017) [26, 37, 16]. Hence, sustained national and transnational coordination and cooperation are an imperative necessity to eliminate malaria from India as well as from Indian subcontinent.

There are many social misbelieves in tribal society of India, which deprives them from proper diagnosis and treatment. Continuous exposure to Plasmodium parasites leads to asymptomatic carriers that provide a fundamental reservoir of parasites and contributes to the persistent transmission of malaria (Kumar, 2019) [37]. In the forest fringe tribe, asymptomatic malaria is mostly prevalent in low socio-economic groups; particularly in inter border areas, including both inter province and international borders (Dhiman *et al*., 2018)[18]. Incidentally prevalence of asymptomatic malaria in tribal women is high. Another fact that escalates the problem is the presence of *P. falciparum* in two Indian, non-human primate species *Macaca mulatta* and *Macaca radiata*. This finding does indicate a possible zoonotic source of *P. falciparum* infection, like *P. knowlesi* in human. At a time when India is committed to eliminating malaria by 2030, this zoonotic probability is a matter of great concern (Ghosh and Rahi, 2019) [20]. The problem of asymptomatic malaria is not well-researched and comprehended in India, although it forms a silent parasite reservoir that will continue to drive transmission especially during high transmission season and in the high burden states of the country (Kumar and Rahi 2019) [20, 37]. For example, in Thailand, despite a great decline in malaria incidences in recent years, transmission is going on at levels undetectable by microscopy, which is traditionally used (Baum *et al*., 2016) [5]. It can thus be said in this context that without appropriate measures for surveillance and comprehensive control measures of asymptomatic malaria especially in tribal areas, the goal of malaria elimination by 2030, can be a difficult challenge. Establishment and implement of certain preventive measures through communication and awareness programs including application of proper vector control strategy for tribal malaria seems to be necessary for the success and sustenance of malaria elimination in India by 2030.

7. Conclusion

The 2030 target for malaria elimination from India might be deemed as an achievable feat considering the impressive progress in malaria control. However, keeping in view the above perspectives of malaria situation in tribe dominated areas in India coupled with climate change and various socioeconomic factors, achieving the above deadline i.e., year 2030 for malaria elimination appears to be very difficult and might be an overambitious notion. Therefore, a comprehensive eco-epidemiological study encompassing various tribe dominated regions of the country is required to formulate an inclusive policy and area-wise strategy for the elimination of tribal malaria. Sustained campaign in this direction would be helpful in overcoming the existing hurdle of complex tribal malaria scenario in India and consequently objective of malaria elimination from India can be achieved by 2030.

8. Acknowledgements

The authors are grateful to Professor A. K. Hati, Former Director Calcutta School of Tropical medicine for his suggestions and encouragement during the work and Dr. Deepchandan Chakrabarty, Assistant Professor of post graduate department of Asutosh College for his help in preparing the manuscript.

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