Mosquito-borne diseases in Assam, north-east India: current status and key challenges

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ABSTRACT

Mosquito-borne diseases, including malaria, Japanese encephalitis (JE), lymphatic filariasis and dengue, are major public health concerns in the north-eastern state of Assam, deterring equitable socioeconomic and industrial development. Among these, malaria and JE are the predominant infections and are spread across the state. The incidence of malaria is, however, gradually receding, with a consistent decline in cases over the past few years, although entry and spread of artemisinin-resistant Plasmodium falciparum remains a real threat in the country. JE, formerly endemic in upper Assam, is currently spreading fast across the state, with confirmed cases and a high case-fatality rate affecting all ages. Lymphatic filariasis is prevalent but its distribution is confined to a few districts and disease transmission is steadily declining. Dengue has recently invaded the state, with a large concentration of cases in Guwahati city that are spreading to suburban areas. Control of these diseases requires robust disease surveillance and integrated vector management on a sustained basis, ensuring universal coverage of evidence-based key interventions based on sound epidemiological data. This paper aims to present a comprehensive review of the status of vector-borne diseases in Assam and to address the key challenges.

Key words: Assam, dengue, Japanese encephalitis, lymphatic filariasis, malaria, north-east India, vector-borne diseases

INTRODUCTION

Vector-borne diseases, including malaria, Japanese encephalitis (JE), lymphatic filariasis and dengue/chikungunya, continue to plague tropical countries globally.¹ These diseases cause considerable illness and mortality in India, where over 1 billion people are living at risk of infection, contributing the majority of cases in the World Health Organization (WHO) South-East Asia Region.²⁻⁴ North-eastern states of India, representing ~4% of the country’s population, are home to all these infectious diseases with indigenous transmission. Among these states, Assam (24°44' to 27°45'N latitude; 89°41' to 96°2'E longitude) alone constitutes 70% of the total population of north-east India (~43 million), and is a major industrial state endowed with a huge rain forest reserve and natural resources. The state is split into 27 administrative districts, which can broadly be classified into three groups of districts, namely upper Assam, lower Assam and south Assam, marked by major river systems and valleys supporting diverse fauna and flora. A vast majority of the population is rural (~80%) and an estimated 36% of the population lives below the poverty line.⁵

Apart from tea plantations (the cash crop), paddy cultivation, livestock and sericulture are the major occupations for subsistence. The climate is typically subtropical, with hot and humid summers and severe monsoons followed by mild winters. The region receives heavy rainfall (2–3 m annually), on account of extended monsoons, beginning with pre-monsoon activity during March/April and maximum precipitation during May to September/October. During this period (wet season), temperatures range from 23 °C to 34 °C and many parts of the state are affected by waves of flash floods each year. Monsoons start to retreat in October, with a concomitant fall in temperatures, and minimum temperatures of 9 °C to 10 °C are recorded during December/January (winter season). The high relative humidity (60–80%) throughout the year is conducive to proliferation and longevity of disease vectors, permitting active transmission of the causative parasites.

Despite accumulated knowledge on disease epidemiology and additional inputs under the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM), these communicable diseases continue to inflict ill health and deter equitable...
socioeconomic development across India. Assam is currently witnessing rapid ecological changes, owing to unprecedented population growth on account of human migration, urbanization and environmental degradation; this creates opportunities for vector proliferation and increased receptivity. Given the health infrastructure and interventions for disease management, malaria, JE and lymphatic filariasis continue to persist, while dengue is a relatively recent introduction and emerging as a public health concern in Assam, with imminent threat to the other north-eastern states of India. This review aims to present a comprehensive overview of the present status of vector-borne diseases, with major emphasis on malaria, JE, lymphatic filariasis and dengue/chikungunya, using unpublished data from the State Disease Surveillance Programme.

**MALARIA**

Malaria is a major public health illness in Assam. All districts are co-endemic for *Plasmodium falciparum* and *P. vivax*. The transmission intensities vary across districts and are estimated to be low to moderate. *P. falciparum* is the predominant infection and is solely responsible for a high proportion of cases and attributable deaths (see Table 1). However, the disease is unevenly distributed, with a large concentration of cases in marginalized population groups of a few districts. For data based on 2011–2013, most districts reported <1 annual parasite incidence (API), apart from five districts, namely two autonomous hill districts of Karbi Anglong and North Cachar Hills (Dima Hasao), and three districts of Chirang, Kokrajhar Udalguri that share an international border with Bhutan; these districts are all categorized high risk for consistently reporting an annual case incidence ≥2 per 1000 population (see Figure 1). All five districts have large concentrations of indigenous ethnic tribes (>30%) and vast forest cover (>40% of land area), and have scattered population settlements (<100 per km²) living under impoverished conditions and lacking awareness of disease prevention and treatment. Furthermore, these districts share either an interstate or international border, and population groups living close to the border/forest fringe continue to have poor access to health-care services.

Transmission of the causative parasites is typically perennial, with a high rise in cases during April to September, corresponding to the wet season/months of heavy rainfall. Cases were also recorded in other months of the year (dry season) but the intensity of transmission was less marked (see Figure 2). This transmission pattern was quite consistent but trends showed a clear and steady decline each year, evidenced by a substantial reduction in the number of cases. However, the number of reported cases may be minuscule in comparison to the actual disease burden, which includes many more unreported/undiagnosed/misdiagnosed cases and those treated in the private/public sector, which are normally not captured by the state surveillance. Furthermore, there is a huge asymptomatic reservoir (estimated to be 8–33% of ethnic communities), for which there is no mechanism for case detection and treatment.

Despite the case-management and chemotherapeutic options in place, *P. falciparum* continues to be the predominant infection (70%), and the threat of resurgence looms large, on account of parasite diversity and evolution of drug resistance over time and space. Ever since detection of chloroquine-resistant malaria in the Karbi Anglong district of Assam in 1973, drug-resistant foci have multiplied and the parasite has become mono- to multi-resistant. The distribution range is rapidly expanding, and the north-east region of India is considered the corridor for spread in the country and beyond. Consequently, there has been steady increase nationally in the proportion of *P. falciparum* over the past few decades, to a current level of about 50% of the total number of cases in the country. Mosquito fauna are rich and breeding sites are diverse and numerous. Of the six dominant vector species in India, *Anopheles minimus s.s.* and *An. baimaii* have been repeatedly incriminated and are widely prevalent. Both these mosquito species have a strong predilection for human blood and have been unequivocally proven, by many independent investigators, to be efficient vectors. Of these, *An. minimus* is the most predominant and widespread across the state in the valley areas, breeding in the foothill perennial seepage water streams. *An. baimaii*, on the other hand, has restricted distribution, with predominance in districts sharing either an interstate or international border with adjacent vast stretches of deep forest reserve (State Entomologist, Integrated Disease Surveillance Project, Assam, unpublished).

Even though both *An. minimus s.s.* and *An. baimaii* remain highly susceptible to DDT (the residual insecticide currently used in the programme), malaria transmission continues in large parts of the state. This is due to high refusal rates by communities for spraying indoors (>50%), inadequate coverage in scheduled times and places, and behavioural characteristics of mosquito species for outdoor resting populations. However, the population densities of both these mosquito species are reportedly depleting, owing to deforestation and urbanization, correlated to reducing levels of malaria transmission. The ecological niche thus vacated is being occupied by *An. culicifacies*, an important vector in the plains of India. To circumvent these issues, the advent of long-lasting insecticidal nets (LLINs) has proven a boon as an alternative intervention against malaria transmission that is accepted as being community based and particularly appropriate in north-east India. The ecological niche thus vacated is being occupied by *An. culicifacies*, an important vector in the plains of India. To circumvent these issues, the advent of long-lasting insecticidal nets (LLINs) has proven a boon as an alternative intervention against malaria transmission that is accepted as being community based and particularly appropriate in north-east India. The ecological niche thus vacated is being occupied by *An. culicifacies*, an important vector in the plains of India. To circumvent these issues, the advent of long-lasting insecticidal nets (LLINs) has proven a boon as an alternative intervention against malaria transmission that is accepted as being community based and particularly appropriate in north-east India. Today, elimination of malaria is feasible with scientific approaches as envisaged by WHO. The main components of the strategy comprise case surveillance; ensuring early diagnosis using rapid diagnostic kits and/or microscopy; vector control by indoor residual spraying and LLINs; and treatment with evidence-based artemisinin-based combination therapy. There are other supportive elements of community participation and awareness programmes that use information, education and communication to prevent creation of habits for vector proliferation; strengthening public health services for improved access to treatment and monitoring of artemisinin resistance; prevention of malaria invasion from the neighbouring states/countries; and resource mobilization, which should all be applied in keeping with the global plan for an artemisinin-resistance containment programme, to prevent the spread of drug-resistant parasites.
Table 1: Malaria-attributable morbidity and vector-control interventions in Assam, north-east India, 2009–2013*

<table>
<thead>
<tr>
<th>Year</th>
<th>Population in millions</th>
<th>Blood smears</th>
<th>Blood smears</th>
<th>Positive for malaria parasite, n (%)</th>
<th>Positive for Plasmodium falciparum, n (%)</th>
<th>% of positive blood-smears with Plasmodium falciparum</th>
<th>Annual parasite incidence (number of confirmed cases per 1000 population)</th>
<th>Target population in millions for DDT spray coverage (% coverage)</th>
<th>Number of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>31.27</td>
<td>302 1915 (9.66)</td>
<td>91 413 (3.03)</td>
<td>66 557 (2.20)</td>
<td>73</td>
<td>2.92</td>
<td>8.54 (71)</td>
<td>7.48 (55)</td>
<td>63</td>
</tr>
<tr>
<td>2010</td>
<td>31.35</td>
<td>430 9267 (13.75)</td>
<td>66 716 (1.55)</td>
<td>48 330 (1.12)</td>
<td>72</td>
<td>2.13</td>
<td>6.66 (81)</td>
<td>7.72 (68)</td>
<td>36</td>
</tr>
<tr>
<td>2011</td>
<td>32.03</td>
<td>4 130 216 (12.89)</td>
<td>47 397 (1.15)</td>
<td>34 807 (0.84)</td>
<td>73</td>
<td>1.48</td>
<td>5.55 (65)</td>
<td>5.61 (70)</td>
<td>45</td>
</tr>
<tr>
<td>2012</td>
<td>32.45</td>
<td>397 3341 (12.24)</td>
<td>29 999 (0.76)</td>
<td>20 579 (0.52)</td>
<td>69</td>
<td>0.92</td>
<td>5.13 (67)</td>
<td>5.02 (70)</td>
<td>13</td>
</tr>
<tr>
<td>2013</td>
<td>32.91</td>
<td>3 895 330 (11.83)</td>
<td>19 542 (0.50)</td>
<td>14 969 (0.38)</td>
<td>77</td>
<td>0.59</td>
<td>4.28 (70)</td>
<td>3.62 (73)</td>
<td>7</td>
</tr>
</tbody>
</table>

aData source: State Health Directorate of Assam (unpublished).
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Figure 1: District map of Assam stratified by annual parasite incidence (API) for data based on 2011–2013. High-risk districts reporting >2 cases per thousand population are colour coded with red (data source: State Health Directorate of Assam, unpublished). API denotes the number of cases per 1000 population/year (data source, State Health Directorate of Assam). Inset is the map of India, showing the geographical location of Assam in the north-east region.

Figure 2: Monthly distribution of malaria cases in Assam, north-east India, 2010–2013 (data source: State Health Directorate of Assam, unpublished).
The earliest record of an outbreak of JE in Assam dates back to 1978 in Lakhimpur district; since then, cases and deaths have been reported in each consecutive year.\textsuperscript{21,22} From reports based on data in 1991, 2004 and 2014, it was apparent that the case incidence was significantly higher in the age group <15 years compared with >15 years, generally in the ratio of 2:1 in males to females.\textsuperscript{23} Districts of upper Assam, including Dhemaji, Dibrugarh, Golaghat, Jorhat, Lakhimpur, Sibsagar and Tinsukhia, were high risk with a history of repeated JE outbreaks and deaths. The clinical presentation of patients with high fever and neurological complications closely mimics JE but recent serological investigations have revealed that a group of arboviruses other than JE are also prevalent and circulating in the region, for example, West Nile virus.\textsuperscript{24,25} All patients presenting with neuropathy are thus broadly categorized as acute encephalitis syndrome (AES), unless confirmed for JE by detection of immunoglobulin M (IgM) antibodies in serum, using IgM antibody capture enzyme-linked immunosorbent assay (MAC ELISA). Analysis of available data based on the State Disease Surveillance Programme (data source: State Health Directorate of Assam, unpublished) revealed that <50% of AES cases were confirmed as JE (see Table 2). The cumulative case-fatality rate inclusive of both AES and JE for 2008–2013 varied from 17% to 31% across all age groups.

The implicated disease vectors, \textit{Culex vishnui} group (\textit{C. tritaeniorhynchus}, \textit{C. vishnui} and \textit{C. pseudovishnui}), are widely prevalent, breeding predominantly in paddy fields. For data based on 2013, these mosquito species were proven susceptible to pyrethroid and malathion adulticides used in the control programme.\textsuperscript{26} The disease is a serious illness with lifelong neuropsychiatric sequelae, and the risk of infection is assessed to be high for geographical locations of human habitation near paddy fields/water bodies (the breeding habitat of JE vectors), with the presence of pigs (the amplification host) in close vicinity, and low socioeconomic population groups facilitating disease transmission. The menace of JE is growing and spreading in areas hitherto free from the disease, with increased morbidity and mortality.

### Table 2: Morbidity due to acute encephalitis syndrome (AES) and Japanese encephalitis (JE) in Assam, north-east India\textsuperscript{a}

<table>
<thead>
<tr>
<th>Year (number of reporting districts)</th>
<th>Number of AES and JE cases\textsuperscript{b}</th>
<th>Number of deaths</th>
<th>Case-fatality rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 (9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>319</td>
<td>100</td>
<td>31</td>
</tr>
<tr>
<td>JE</td>
<td>157 (49%)</td>
<td>33</td>
<td>21</td>
</tr>
<tr>
<td>2009 (13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>643</td>
<td>109</td>
<td>17</td>
</tr>
<tr>
<td>JE</td>
<td>218 (34%)</td>
<td>46</td>
<td>21</td>
</tr>
<tr>
<td>2010 (21)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>495</td>
<td>117</td>
<td>24</td>
</tr>
<tr>
<td>JE</td>
<td>154 (31%)</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>2011 (24)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>1491</td>
<td>281</td>
<td>19</td>
</tr>
<tr>
<td>JE</td>
<td>533 (36%)</td>
<td>114</td>
<td>21</td>
</tr>
<tr>
<td>2012 (23)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>1439</td>
<td>267</td>
<td>19</td>
</tr>
<tr>
<td>JE</td>
<td>486 (34%)</td>
<td>107</td>
<td>22</td>
</tr>
<tr>
<td>2013 (27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>1396</td>
<td>276</td>
<td>20</td>
</tr>
<tr>
<td>JE</td>
<td>496 (36%)</td>
<td>134</td>
<td>27</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Data source: State Health Directorate of Assam (unpublished).

\textsuperscript{b}Figures in parenthesis denote JE as a percentage of total AES cases.
Figure 3: Distribution of Japanese encephalitis (JE) cases in Assam, north-east India, by age group, 2010–2013 (data source: State Health Directorate of Assam, unpublished)

Figure 4: Monthly distribution of Japanese encephalitis (JE) cases in Assam, north-east India, 2010–2013 (data source: State Health Directorate of Assam, unpublished)
To reduce morbidity and case-fatality, the state has taken up bold initiatives under the National Health Mission, including establishing (i) paediatric intensive care units; (ii) physical medical rehabilitation departments; (iii) additional sentinel sites for strengthening disease surveillance (13 sites across the state); and (iv) capacity-building for training of trainers and recruitment of additional medical professionals, in order to strengthen health-care services. For containment of JE spread, provisions are made for thermal malathion fogging in high-risk areas and impregnation of community-owned mosquito nets for proven efficacy; application of larvivorous fish for control of mosquito breeding; and health-education/awareness programmes for community action. In addition, vaccination campaigns are routinely conducted in the endemic districts for protection of vulnerable population groups, achieving >70% coverage of the target population for immunization; provisions have also been made for special rounds of immunization in high-risk districts; and, beginning in 2013, a pilot project study for a JE vaccination programme for adults (for the first time in the country) was taken up in select districts for mass protection and to avert disease outbreaks (data source: State Health Directorate of Assam, unpublished).

**LYMPHATIC FILARIASIS**

Bancroftian filariasis (Wuchereria bancrofti) is prevalent in Assam but disease has been recorded in only seven districts, namely Darrang/Udalguri, Dhemaji, Dhubri, Dibrugarh, Kamrup/Kamrup (Metro) and Nalbari/Baksa Sibsagar (data source: State Health Directorate of Assam, unpublished). This reporting is based on indigenous transmission evidenced by clinical cases and microfilariae carriers in the communities (see Table 3). The mosquito vector, Culex quinquefasciatus is a common household mosquito and constitutes a major source of nuisance throughout the rural/urban areas of the region. It has been repeatedly incriminated with a high rate of infection (6.1%) and infectivity (4.6%) of the L3 parasite of *W. bancrofti* in disease-endemic districts, and recorded breeding in a variety of polluted water bodies, for example, open drainage, sewage water collections and ditches, often in close proximity to human habitations. Surveys of the prevalence of filariasis in these districts have revealed a significantly higher microfilaria rate (4.7–10.3%) in tea garden tribes (descendants of migrated tribes from West Bengal, Bihar, Madhya Pradesh, Odisha and Uttar Pradesh), as against the indigenous populations living in close vicinity to a tea garden, which could be attributed to variation in sociocultural living conditions and host–parasite response. The microfilaria rates, however, were consistently higher in males than females. In these communities, cases of chronic filariasis with involvement of the genitals were more common than those involving the lower extremities.

For control of filariasis, beginning in 2005, seven endemic districts were subjected to annual rounds of mass drug administration (MDA) of diethylcarbamazine + albendazole in eligible population groups, that is, excluding children aged <2 years, pregnant women and seriously ill persons. Additional measures included home-based management of lymphoedema cases and scaling up of hydrocele operations in the identified

<table>
<thead>
<tr>
<th>District</th>
<th>Year</th>
<th>Population (% coverage under MDA)</th>
<th>Number of lymphatic filariasis cases</th>
<th>Number of hydrocele cases</th>
<th>Microfilariae rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibrugarh</td>
<td>2010</td>
<td>1 345 751 (77)</td>
<td>438</td>
<td>430</td>
<td>1.69</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>1 349 624 (84)</td>
<td>494</td>
<td>603</td>
<td>1.46</td>
</tr>
<tr>
<td>Dhemaji&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2010</td>
<td>677 875 (93)</td>
<td>18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>692 004 (94)</td>
<td>31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dhubri&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2010</td>
<td>1 755 760 (90)</td>
<td>142</td>
<td>317</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>1 843 768 (86)</td>
<td>128</td>
<td>292</td>
<td>0</td>
</tr>
<tr>
<td>Kamrup/Kamrup (Metro)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2010</td>
<td>2 980 089 (85)</td>
<td>44</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>3 316 179 (81)</td>
<td>44</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Nalbari/Baksa&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2010</td>
<td>1 833 738 (82)</td>
<td>28</td>
<td>142</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>1 870 635 (73)</td>
<td>28</td>
<td>142</td>
<td>0</td>
</tr>
<tr>
<td>Sibsagar</td>
<td>2010</td>
<td>1 148 572 (82)</td>
<td>129</td>
<td>170</td>
<td>3.01</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>1 163 655 (90)</td>
<td>282</td>
<td>334</td>
<td>0.67</td>
</tr>
<tr>
<td>Darrang/Udalguri&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2010</td>
<td>1 815 448 (81)</td>
<td>280</td>
<td>397</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>1 863 755 (77)</td>
<td>120</td>
<td>132</td>
<td>0</td>
</tr>
</tbody>
</table>

MDA: mass drug administration.

<sup>a</sup>Data source: State Health Directorate of Assam (unpublished).

<sup>b</sup>Districts excluded from MDA round in 2013 and targeted for transmission assessment surveys in 2014.
community health centres/district hospitals/medical colleges. With more than five consecutive MDA rounds with >70% coverage in target districts, there has been substantial progress in depleting the asymptomatic reservoir, with a state average microfilaria rate of 0.15%, as against a national average of 0.27% in 2013. Consequently, out of the total of seven endemic districts, five were excluded from MDA in 2013 and were scheduled for transmission assessment surveys (TASs) in 2014, using an immunochromatographic test (ICT) for the presence of circulating antigen in children born after the initiation of MDA. In these surveys, filarial antigen positivity was observed to be zero in Darrang/Udalguri and Dhemaji districts, and varied from 0.12% to 0.64% of the total subjects screened in Dhubri, Kamrup and Nalbari/Baksa districts (K Nath, Directorate of Health Services, Assam, personal communication). The remaining two districts of Dibrugarh and Sibsagar were assessed to be eligible for another round of MDA, as they reported a microfilaria rate of >1% of the population surveyed, and they were scheduled for TAS in 2015.

Filarial endemicity is steadily declining to meet the national goal of filarial elimination by 2015. The state health department is continuously strengthening health-care services for better case management, coupled with mass awareness campaigns for disease prevention. For control of disease vectors, interventions are applied by recurrent anti-larval measures in urban areas, combined with sanitary measures including filling ditches, pits and low-lying areas, de-weeding, de-silting, application of larvivorous fish, and, for control of the adult mosquito population, thermal fogging operations carried out on a continuing basis.

**DENGUE/CHIKUNGUNYA**

Dengue arbovirus has recently emerged as a major public health concern with increased morbidity in Assam. In 2010, for the first time, 237 dengue cases were reported, followed by 1058 and 4526 cases in 2012 and 2013, respectively (data source: State Health Directorate of Assam, unpublished). Most dengue cases (>70%) were recorded in Guwahati metropolitan area during the post-monsoon months in September to December. Among these, patients comprised all age groups of both sexes but there was a higher concentration of cases in adult males aged 26–60 years. Dengue is currently spreading to semi-urban areas and adjoining districts/states of north-east India.

*Aedes aegypti* and *Ae. albopictus* are implicated as disease vectors for the spread of dengue and chikungunya, and breed in a variety of containers. Among these, *Ae. aegypti* has been incriminated for the circulating serotype of dengue virus 2, in both males and females, establishing transovarial transmission in the region (P Dutta, Regional Medical Research Centre, Dibrugarh, personal communication). It is a common species in city premises and recorded breeding is predominantly in discarded tyres and solid waste containers. *Ae. albopictus*, on the other hand, is commonly encountered in semi-urban/rural areas, breeding in tin/plastic containers, flower vases, cut-bamboo stumps, etc. Along with dengue, few cases of chikungunya were recorded in 2012 (five cases) and 2013 (78 cases); these cases were negative for dengue antigen antibody assays and other AES viruses. Studies on seasonal infectivity and co-circulation of these viruses are warranted, to enable better understanding of transmission dynamics, thereby helping the state control programme to prepare mitigating plans to respond to these imminent threats.

Both these mosquito vector species are reported to be susceptible to malathion, the insecticide of choice for fogging operations. For data based on disease prevalence and records of mosquito breeding, it is imperative that the disease has an established foothold in the state, with indigenous transmission corroborated by listing of cases without any travel history.

With the continued phenomenon of urbanization and prevailing climatic conditions, it is projected that dengue will emerge as a major public health concern in north-east India. For disease containment, besides malathion thermal fogging operations, source reduction and promoting personal protection measures, the state control programme has embarked upon an intensive health-awareness campaign for enhanced community-level action for prevention and control of mosquito breeding, in collaboration with the local civic bodies.

**DISCUSSION**

Among vector-borne diseases, malaria and JE are the major public health problems in Assam. However, the threat of malaria is gradually receding, with a consistent decline in cases over the past few years, owing to implementation of newer interventions in the control programme since 2008, assisted under GFATM, namely LLINs/impregnation of community-owned mosquito nets for vector control, and artemisinin-based combination therapy for treatment, and, above all, making provisions for induction of accredited social health activists, to ensure early diagnosis at the local and individual level. The existing health-care infrastructure is being further augmented under the National Health Mission in the state, for a quality health-care and outreach programme.

However, there are many more challenges that remain to be addressed to qualify for pre-elimination specific to Assam/north-east India. To enumerate a few, the problem of asymptomatic malaria (parasite reservoir in the community) remains unattended, leaving many cases untreated and inadequate vector-control interventions along international/interstate borders; this requires priority action to achieve a substantial reduction of transmission. In addition, Assam is the major contributor for *P. falciparum* malaria that has become multi-resistant, and treatment of this remains a continuing challenge. There are already confirmed reports of declining response to ACT (artesunate + sulfadoxine–pyrimethamine) in the north-east of India, resulting in a shift of drug policy to AL (artemether + lumefantrine). Nevertheless, although there is no evidence for resistance to artemisinin in Assam/north-east India, the threat of import of artemisinin resistance across borders from neighbouring countries, where it has already surfaced, looms large. To contain the entry of artemisinin resistance, there is an imperative need for robust disease surveillance, periodic monitoring of the therapeutic efficacy of the drug regimen in force for effective radical cure.
and intercountry collaboration for coordinated vector control to prevent its spread. Equally important would be to step up pharmacovigilance, preventing circulation of counterfeit drugs and enforcing application of a uniform drug policy among private practitioners and discontinuing monotherapies. It is strongly advocated to universalize interventions for prevention and access to treatment, prioritizing high-risk areas for keeping malaria at bay. The authors strongly advocate community-driven actions for increased awareness of disease and its prevention, with political commitment for sustained allocation of resources for uninterrupted supply of logistic requirements. With Bhutan and Sri Lanka heading for malaria elimination in the WHO South-East Asia Region, it is time for India to re-strategize to achieve a pre-elimination stage, with the focus on attention on the north-east sector, by greater allocation for scaling up interventions and health-delivery mechanisms in hard-to-reach population groups at high risk of malaria, thereby preventing the spread of drug-resistant malaria.

Cases of JE are emerging in all districts across the state, with increased morbidity and case-fatality. There is no breakthrough for control, apart from immunization to prevent JE cases. The future priority area of research should include understanding the epidemiology of AES, which remains to be resolved for the group of viruses responsible, and incriminating disease carriers. Vector control is an expensive and formidable exercise to cover affected populations year after year. It is high time for programme and policy managers to make sound investments in health-care services for intensive disease surveillance, reporting mechanisms, enhanced immunization coverage and augmentation of infrastructure providing supportive therapy for relieving clinical symptoms.

Filarial endemicity is steadily declining, with consecutive rounds of MDA, case management and increased awareness of disease prevention. Filariasis is no longer perceived to be a threat in the state and elimination is seemingly achievable with continued interventions. MDA rounds are no longer planned in the state and, given the mandate for filarial elimination, TASs are scheduled in 2015 in the two problematic districts of Dibrugarh and Sibsagar.

Dengue is now endemic and spreading, owing to the continued phenomenon of urbanization and increased air travel/business activities. As for dengue, cases of chikungunya were also confirmed serologically in 2011 and it is believed to be co-circulating. As there is no effective vaccine to date, efforts should be focused on early detection and proper case management, to reduce morbidity and mortality, supported by mass community awareness and participation for prevention of mosquito-vector breeding.

In conclusion, the disease burden due to vector-borne diseases in Assam is enormous and likely to perpetuate. It is strongly advocated that for control of these diseases, including malaria, JE, lymphatic filariasis and dengue/chikungunya, a comprehensive and integrated approach that is community driven, cost-effective and sustainable must be applied. In the changing ecological context, knowledge and understanding of disease epidemiology is critical for formulating control interventions to check the spread of disease. The authors strongly believe that programme ownership and leadership, innovation in tools and implementation approaches, improved disease surveillance, monitoring and evaluation, judicious application of a combination of technologies, human resource development, and equity in access to services would help accelerate progress in achieving the ultimate goal of freedom from vector-borne disease.

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