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Burden of Infectious Diseases in North East India: A Mini-Review

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Abstract

North East India, with its unique geographical and cultural characteristics, bears a significant burden of infectious diseases. This mini review provides an overview of the prevalent infectious diseases in the region, highlighting the highest disease burden and the most endemic diseases. Malaria emerges as a major public health concern, with frequent outbreaks and substantial morbidity and mortality. Dengue fever, tuberculosis, Japanese encephalitis, Chikungunya, rickettsia diseases, waterborne enteric infections, hepatitis, and HIV/AIDS are also prevalent in the region. Challenges such as rugged terrain, limited transportation infrastructure, limited healthcare infrastructure, inadequate diagnostics, socio-economic factors and sharing of international border with four neighboring countries etc hinder disease control efforts. Strengthening vector control, improving diagnostics, expanding healthcare access, and raising community awareness are crucial strategies for reducing the burden of infectious diseases. Surveillance and research efforts are needed to enhance understanding and control of these diseases. Febrile illness like Scrub typhus stands out as the most endemic disease in the hilly regions, characterized by high prevalence, associated morbidity and mortality, and a lack of knowledge about its epidemiology and impact. Active surveillance is crucial to better understand the burden and distribution of the disease and address the challenges in the region.

Keywords: Infectious Disease; Northeast India; Burden

Abbreviations: Pf: *Plasmodium falciparum*; Pv: *Plasmodium vivax*; IMCP: Integrated Malaria Control Program; LLINs: Long-lasting Insecticidal Nets; RDTs: Rapid Diagnostic Kits; API: Annual Parasite Incidence ; NVBDCP: National Center for Vector Borne Disease Control; DENV: Dengue; TB: Tuberculosis; JE: Japanese Encephalitis; JEV: Japanese Encephalitis Virus; CFR: Case Fatality Rate; NE: North-East; HBV: Hepatitis B Virus; HCV: Hepatitis C Virus; MoHFW: Ministry of Health and Family Welfare; CHIKV: Chikungunya Virus; ICMR:Indian Council of Medical Research; HIV: Human Immunodeficiency Virus; AIDS: Acute Immunodeficiency Syndrome; DR: Drug-resistant; CDC: Centers for Disease Control and Prevention; MDR: Multi Drug Resistant; IDU: Injecting Drug Use; WNV: West Nile Virus; AES: Acute Encephalitis Syndrome; MERA India: Malaria Elimination Research Alliance India; MESA: Malaria Eradication Scientific Alliance; PTB: Pulmonary Tuberculosis; EPTB: Extra-pulmonary Tuberculosis; CI: Confidence Interval; AES: Acute Encephalitis Syndrome; IoT: Internet of things; NACP: National AIDS and STD (Sexually transmitted diseases) Control Program; AI:Artificial Intelligence; AR: Augmented Reality; VR: Virtual Reality; QC: Quantum Computing.

Introduction

NE India, comprising the seven sister states (Assam. Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura) and the Himalayan state of Sikkim, is a diverse region characterized by unique geographical, cultural, and environmental factors [1,2]. This region is prone to various infectious diseases due to its climatic conditions, dense forests, and limited healthcare access in certain areas [3]. The NE region shares international borders with neighboring countries like Bhutan, China, Myanmar and

Bangladesh [4]. This geographical proximity with south east Asian countries, coupled with increased cross-border movements, contributes to the challenges in preventing and controlling infectious diseases [5]. The region's rugged terrains, dense forests, and remote areas further complicate healthcare delivery and surveillance efforts, making it susceptible to transmission of infections and outbreaks [6]. NE India is affected by a range of endemic infectious diseases, which impose a substantial burden on public health [7]. The region exhibits a high prevalence of communicable diseases, including malaria, DENV, Scrub typhus and JE all transmitted through vectors [7]. Water-borne illnesses, such as typhoid, cholera, and diarrheal diseases, are prevalent due to inadequate sanitation facilities, lack of awareness and limited access to safe drinking water [8,9]. Moreover, a significantly diminished sensitivity pattern of antitubercular drugs is seen in Meghalaya [10]. HIV/AIDS and respiratory infections are also significant health concerns within the region [11-14].

The challenges in addressing infectious diseases in NE India are multifaceted. Limited healthcare infrastructure, non-availability of point of care diagnostics, inadequate healthcare access in remote areas, and scarcity of trained healthcare professionals hinder the effective management and control of these diseases. Socio-economic factors, including poverty, illiteracy, and lack of awareness, further contributes to the vulnerability of the population [15]. To address the complex landscape of infectious diseases in NE India, it is crucial to have a comprehensive understanding of the epidemiology, aetiology and impact of these diseases in the region. This mini review aims to provide an overview of the prevalent infectious diseases in NE India, their public health implications, and the challenges associated with their prevention and control. Additionally, the review will highlight the ongoing efforts and strategies implemented to mitigate the burden of infectious diseases in the region.

Malaria

Malaria is a potentially life-threatening disease caused by the Plasmodium parasite. It is transmitted to humans through the bites of infected female Anopheles mosquitoes [16]. Globally malaria poses a significant threat primarily to children and has exerted considerable evolutionary pressure on the human genome, making it one of the most impactful factors in recent evolutionary history [17]. Malaria remains a significant public health concern in NE India (Figure 1). Frequent outbreaks of Pf, the main parasite species, result in substantial morbidity and mortality in the region [18]. In a cross-sectional mass survey (n=8,233) to screen malaria and anemia prevalence in two high and low endemic districts of NE India, it was reported that 79.6% malaria prevalence in East Garo Hills of Meghalaya and 20.4% in Udalguri district of Assam respectively [19].

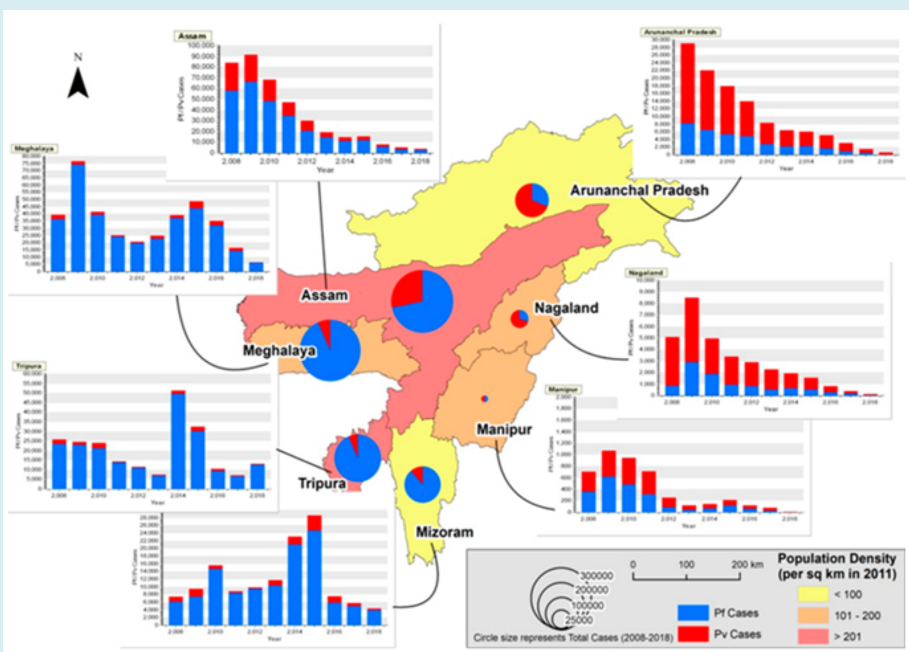

Figure 1: From 2008 to 2018, the spatio-temporal distribution of Pf and Pv cases in NE India was analyzed. Background color denoted state population density based on the 2011 census. Pie-charts illustrated reported Pf and Pv cases, with Pv data derived by subtracting Pf cases from total malaria cases due to NVBDCP data limitations [20].

States such as Assam, Arunachal Pradesh, and Tripura bear a disproportionate burden of malaria cases due to factors like forested areas, favourable climate, and inadequate vector control measures [21]. The IMCP launched in 2005 aimed to combat malaria in NE India. A study in Udalguri, Assam, assessed the IMCP's impact, which included LLIN distribution, bi-valent rapid diagnostic kits, and malaria awareness programs. The results showed a significant decline in API with 37% reduction after LLINs in 2009 and a further 64% reduction after RDTs. Udalguri major malarial parasites were Pf (29%) and Pv (71%) [22].

During 2019, Dr. Balram Bhargava, the Director General of the Indian Council of Medical Research (ICMR), launched a significant initiative called "MERA India" on the occasion of 'World Malaria Day'. With an objective to bring together government agencies, research institutions for conducting research and implement evidence-based strategies. Aim of MERA-India is to unite researchers and national programs working on malaria, with alliance focus on reducing malaria cases and achieving eventual eradication. It promotes multicenter studies to provide comprehensive "pan-India data" for malaria elimination efforts [23]. On the other hand MESAis an international initiative aimed at accelerating the development of tools and strategies for malaria eradication worldwide. It was launched by a consortium of global organizations and institutions in 2012. It is an initiative aimed to combat malaria.MESA brings together researchers, scientists, and experts from around the globe to collaborate on research projects and initiatives related to malaria eradication. The alliance's primary focus is on supporting research efforts to develop new tools and intervention such as vector control methods, and diagnostics, which can effectively combat malaria [24,25]. India engages in malaria control and elimination through the NVBDCP employing strategies such as vector control and surveillance, treatment, and research partnerships [26].

Efforts to control malaria have been hampered by difficult terrain, inadequate healthcare infrastructure, and a lack of community awareness. However, initiatives such as insecticide-treated bed nets, indoor spraying, and effective anti-malarial drug distribution have shown promising results in reducing malaria burden [27]. Efforts should focus on strengthening vector control programs, enhancing access to early diagnosis and treatment, and promoting community awareness to reduce the impact of malaria.

Dengue

Dengue fever is a common mosquito-borne illness caused by different serotypes of DENV: DENV-1, DENV-2, DENV-3, DENV-4, and the newly discovered DENV-5 [28,29]. DENV is classified under the Flaviviridae family and possesses a single-stranded, positive-sense RNA as its genetic material [30,31]. Dengue fever is another major concern in the region [32]. A detailed entomological survey conducted from 2004 to 2005 across seven states in the NE region of India indicated a significant presence of diverse mosquito species, particularly *Aedes* and related species. It was observed that the well-known dengue vectors, namely *Aedes aegypti* (Stegomyia) and *Aedes albopictus* (Stegomyia), which are container-breeding mosquitoes, were found in all seven states examined. These findings highlight the widespread presence of these *Aedes*mosquito species in the region [33].

The first reported case of dengue fever in NE India was reported from Pasighat, Arunachal Pradesh, in 2012, with DENV-3 as the predominant serotype, along with DENV-1 and DENV-2 and during 2014, all four DENV serotypes were detected in the region [34]. The DENV outbreaks were attributed to enhanced breeding sites, vector presence, and elevated temperatures associated with El Nino episodes, moreover, mean extrinsic incubation period for mosquitoes shortens at higher temperatures.(34)The overall sero-prevalence of DENV in the NE region was observed to be 5.0% [35]. During 2016-17 Guwahati Medical College and Hospital screened over 21,000 suspected sera samples for DENV (NS1 and IgM antibody) from 17 districts of Assamand 9543 (45.4%) tested positive for DENV and typing showed three serotypes (DENV1, DENV2 and DENV3) and three genotype (V, IV, III) [36]. Inadequate sanitation and water storage practices, lack of awareness, delayed diagnosis, and limited access to appropriate medical care compounds the challenge of dengue control [37]. A comprehensive multi-functional environmental management measures were implemented in Pasighat, which resulted in a significant reduction in reported DENV cases [38]. Similar integrated vector management strategies, public education campaigns, and improved diagnostic facilities are essential for combating dengue in this region.

Tuberculosis

TB is an infectious disease caused by the bacterium Mycobacterium tuberculosis. It belongs to the *Mycobacteriaceae* family of bacteria [39,40]. NE India has a relatively high burden of TB due to poverty, malnutrition, HIV prevalence and high prevalence of MDR TB [41,42]. A significant number of TB patients (53.17%) had comorbidities, primarily diabetes mellitus (26.58%) and hypertension (17.34%). Comorbid conditions were more common in PTB cases than in EPTB cases [43]. The NE India had a prevalence of smear and/or culture positive PTB of 233 cases per lakh (95% CI: 134-331), the prevalence for other regions [44].

Various studies have identified certain factors associated with the higher prevalence of TB in specific populations.

These factors include lower socio-economic status, lower levels of education, unemployment, inadequate housing conditions, alcohol consumption, proximity to individuals with TB, travel history, lack of BCG vaccination, air borne transmission, participation in mass gatherings, and suboptimal weight status [45]. The region's hilly terrain and remote communities pose challenges in delivering healthcare services, including TB diagnostics and treatment. Strengthening healthcare infrastructure, expanding access to quality diagnostic facilities, and ensuring timely initiation of treatment are crucial to tackling TB in this region.

Japanese Encephalitis

JE is a mosquito-borne (*Culex tritaeniorhynchus*) viral disease that primarily affects children which is caused by the JEV, belongs to the Flavivirus family and is primarily transmitted by Culex mosquitoes [46,47]. The genome of JEV composed of a single-stranded, positive-sense RNA [48]. WNV closely related to JEV is also reported from JEV is endemic regions [49].

Since 1976, JE has been sporadically occurring in outbreaks or epidemics in Assam, primarily due to favorable climatic conditions, the presence of numerous potential mosquito vectors, amplifying hosts, agricultural practices, and socio-cultural behaviors of the local population that contribute to the spread of the disease in the state [50]. More than one-third of the national burden of JE in India comes from the state of Assam alone [51]. In Assam, there has been a significant shift in the prevalence of JE cases by age, unlike other JE-endemic states in India. The number of cases among individuals above 15 years old has increased significantly compared to those below 15 years old. Assam is facing a surge in JE and AES cases, with the disease spreading from upper Assam to all other districts in the state and seasonality of JE is shown in Figure 2 [7].

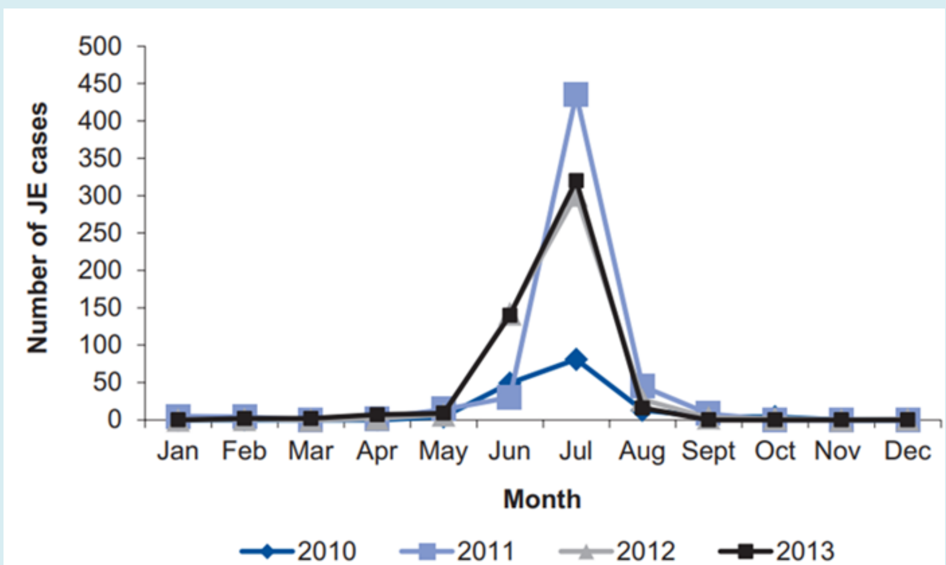

Figure 2: Seasonality of Japanese encephalitis (JE) cases from 2010 to 2013, data from the State Health Directorate of Assam [7].

Incidence of adult JE cases reduced from 10.5 to 5.7 per 100,000 following vaccinations in two districts (Sivasagar and Dibrugarh) of Assam [51]. During 2011 to 2020 reported 1081 AES and 588 JE cases, with 333 and 180 deaths, (CFR 30.61%) respectively from Sivasagar, Assam. And it was also reported that AES/JE cases peaked in June and July and were more common among elderly and males [52]. Routine JE vaccination covered over 50% of the 9-18 months age group. Although AES/JE cases are declining, intensified surveillance and increased immunization coverage are needed [52]. The preventive method available for JE is JE vaccine; early detection and prompt medical intervention are important for effective JE cases. Vaccination programs against the disease have shown effectiveness; primary comprehensive measures such as mosquito control, improving living conditions of vulnerable populations, and health education remain the most effective methods to prevent the disease [53,54].

Waterborne and Enteric Infections

Waterborne and Enteric Infections are caused by various pathogenic microorganisms such as bacteria, viruses, protozoa, and parasites [55]. Inadequate hygiene, sanitation, and polluted water contribute to 6.3% of worldwide fatalities and 9.1% of the overall global burden of disease [56]. Diarrhea is a prominent water-borne disease that is endemic in numerous regions across the world, posing a significant health threat to global populations [57,58]. Rugged terrains, dense forests, and remote areas of NE India offers a diverse range of disease environments, with a predominant presence of communicable diseases (35.68%). Among these, diarrhoea stands out as a water-borne disease that significantly impacts the local society. The prevalence of RV associated diarrhoea among children below 5 years of age in India is 36.3% and prevalence in Nagaland and Assam is 40.3% and 38.4% respectively [59]. Other enteric pathogens like norovirus, adenovirus, campylobacter, sapovirus, astrovirus are also endemic in the region [60,61].

Sikkimese people's use untreated spring water poses a significant threat to public health due to the potential presence of waterborne pathogens [62]. In 2017 and 2018, Sikkim reported alarming cases of 41,816 and 41,449 acute diarrheal diseases, as well as 104 and 158 cases of enteric fever, respectively. A study also revealed severe fecal contamination in Sikkim's spring water, demanding immediate attention [63,64]. The main factors contributing to diarrhoea include Inadequate environmental sanitation, Absence of access to safe drinking water, seasonal flood, contaminated food, and transmission through fomites, flies, and cockroaches. However, the local population, deeply connected to nature, possesses valuable ethno biological knowledge about the plants in their surroundings. This knowledge enables them to effectively prevent and treat various disease complications [65]. Since, waterborne diseases have been a significant public health concern in Northeast India, particularly in areas with limited access to safe drinking water and proper sanitation facilities. Efforts have been made to monitor water quality and improve sanitation infrastructure [66].

Hepatitis

Hepatitis is a condition characterized by inflammation of the liver. It is caused by different hepatitis viruses, categorized as types A, B, C, D, and E, as well as non-infectious factors. Hepatitis can lead to a range of health complications, including potentially life-threatening outcomes [67,68]. Hepatitis B and C infections are a significant health concern in NE India [69]. Earlier studies have reported the prevalence of HBV and HCV in the region and risk factors for transmission, the recent surge in trade, trafficking, and the illicit use of drugs has had a significant impact on the epidemiology of HBV, particularly in the NE regions of India [70]. Among the South-East Asian nations, India falls under the category of intermediate prevalence for hepatitis B (2 to 5%) [71].In the NE region of India, specifically in Tripura, the community-level prevalence of hepatitis B is 3.6% (95% CI 3.14-4.06) [71]. Among Idu Mishmi tribe of Arunachal Pradesh, Hepatitis B virus infection is hyperendemic [72]. High incidence of hepatitis in the region is may be due to IDUs, as 15.9% of the tested injection drug users were found to have contracted HBV infection [73]. The estimated prevalence of Hepatitis B in NE India shows variation, ranging from approximately 2% in states like Assam to as high as 7-8% in Arunachal Pradesh and specific regions of Tripura. The increasing number of IDUs is a contributing factor to the rise in Hepatitis B prevalence and incidence, making it one of the highest in the country [74]. In a study it was reported, 9.9% prevalence of HBV infection among individuals with different liver diseases, blood donors, and healthcare workers in Northeast India and among the infected cases, 49.5% were HBV DNA positive [75].

MoHFWIndia has implemented several significant initiatives to combat Hepatitis infections, including HBV Immunization programs, Viral Hepatitis Surveillance. Surveillance systems are in place to monitor and track cases of viral hepatitis, Injection Safety and Infection Control, Biomedical Waste Management, Research, Awareness Programs. These comprehensive efforts in India working towards preventing new hepatitis infections, improving healthcare practices, and enhancing public awareness to mitigate the impact of hepatitis on individuals and communities [76]. However, further community-based studies should be made to develop more effective measures to combat and control hepatitis in the region.

Chikungunya Virus

CHIKV, an alphavirus classified within the *Togaviridae* family, is a small, spherical enveloped virus with a diameter ranging from 60 to 70 nmThe virus carries a genome comprising a single-stranded RNA molecule of positive polarity [77]. During 2011, the initial documentation of CHIKV infection among hospitalized individuals in Assam came to light [78]. CHIKV has been identified as a prevalent disease in the regions of Assam, Arunachal Pradesh, and Meghalaya [79]. The seroprevalence CHIKV in the NE region is recorded to be (0·3% [95% CI 0·1–0·8]) [80]. During 2014-17 1,510 CHIKV/DENV suspected cases from Assam, Arunachal Pradesh and Meghalaya were screened for CHIKV IgM antibody and 179 samples (11.83%) tested positive and the age group between 16 and 30 years showed the highest incidence [79]. In another study, CHIKV transmission was found to be lower in NE and eastern region (sero-prevalence < 5%) than rest of India [80,81].

CHIKV is generally a self-limiting infection however the rising morbidity caused by CHIKV infection has significant impacts on the social and economic well-being of individuals [82,83]. Therefore, it is essential to implement community empowerment initiatives to effectively control the mosquito population through various mosquito control measures and personal protection methods. These proactive measures are necessary to address and mitigate the potential outbreak of this disease in the future [79].

Scrub Typhus

Scrub typhus is a bacterial infection caused by *Orientia tsutsugamushi*. It belongs to the family *Rickettsiaceae*. The genetic material of *Orientia tsutsugamushi* is composed of single-stranded DNA [84]. Several Scrub typhus outbreaks were reported from North, South, and Eastern India [85,86]. Scrub typhus is endemic in several states of NE India, reported from Assam, Nagaland, Arunachal Pradesh, and Mizoram [84,85,87]. During 2018 to 2022, Mizoram witnessed a total of 22,914 rickettsial cases, out of which 19,651 (85.76%) individuals tested positive for scrub typhus over all incidence rate of rickettsial disease in Mizoram was3.34 [87]. In another sero-surveillance study in seven districts of Arunachal Pradesh showed prevalence of scrub typhus was 25.9% to 72.5% (Figure 3) [88]. The presence of extensive scrub vegetations, occupational (farming) exposure, *Jhum* farming practices, and favourable environmental conditions collectively create a favourable environment for the spread of rickettsial infections [86]. During 2019 district hospital Lawngtlai reported Two (2) unfortunate death from Cheural village, Mizoram and multiple cases having scrub typhus like illness, after investigation of 242 cases, 80 (33.05%) cases found to be scrub typhus positive [89]. The investigation also revealed farmers particularly involved in forest farming under the working age groups (20-60 years) were most affected [89]. Moreover, Leptospirosis a zoonotic disease with multisystemic involvement is caused by the pathogenic strains of *Leptospira interrogans* is also reported from parts of NE region [90].

In less-explored areas of NE India, such as Arunachal Pradesh, Mizoram and other NE states there is a lack of knowledge about the epidemiology and impact of rickettsial diseases. Hence, it could be a significant factor contributing to undiagnosed cases of fever. It is crucial to conduct active surveillance to gain a better understanding of the true extent, epidemiological characteristics, and distribution of the disease's vectors and burden. This will help address the challenges posed by this remerging neglected tropical disease.

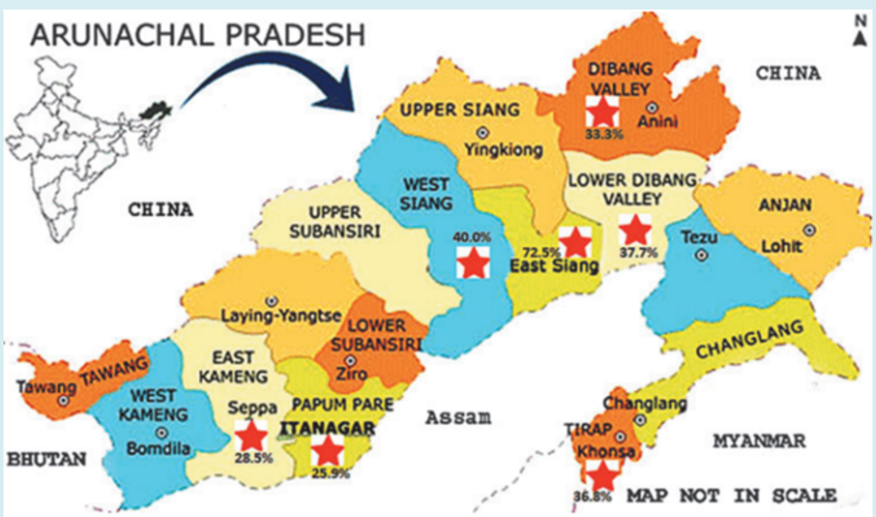

Figure 3: Map of Arunachal Pradesh, indicating the districts under study along with their respective prevalence rates represented in percentages. The study districts are marked with a red star symbol. For visual representation, color images can be accessed online at www.liebertpub.com/vbz [89].

Improving the estimation of scrub typhus burden in India can contribute to the development and implementation of more effective control and management strategies. Enhanced public awareness campaigns, implementation of robust vector control, strengthening healthcare infrastructure will help in combating this neglected tropical disease in NE India.

Human Immunodeficiency Virus

HIV is a virus that targets and compromises the immune system, leading to its weakening and impairment. It belongs to the *Retroviridae* family and has two single-stranded RNA as its genetic material [91]. HIV remains a significant global public health concern, with numerous new infections annually and a staggering death toll of nearly 40.1 million lives so far [92]. The NE states of India, including Mizoram, Nagaland, and Manipur, exhibit the highest rates of adult HIV prevalence, with percentages standing at 2.70%, 1.36%, and 1.05% respectively [93]. The primary factor contributing to the HIV pandemic in this international border region is the utilization of illicit 'heroin' sourced from the 'South Asia Golden Triangle [94]. The HIV pandemic in the border region presents distinctive complexities not encountered in other parts of the country. These complexities stem from the emergence of recombinant HIV forms and DR HIV-1 strains. IDU and intricate patterns of cross-border movement have contributed significantly to the challenges associated with the HIV/AIDS pandemic in the region [95]. Gaining a deeper understanding of the causes, challenges, and current situation of HIV/AIDS is crucial for improving patient investigation and treatment. Additionally, comprehensive studies exploring factors such as the impact of emerging genetic variants on antiretroviral treatment response and the effects of co-infections with different viruses should be conducted at all international borders. These efforts are necessary to curb the spread and limit the expansion of more complex forms of the virus [94].

Mizoram, has the second-highest AIDS mortality rate in the country, standing at 23.34 per 100,000 population [96]. In terms of AIDS-related deaths, there were 58.96 thousand deaths in 2019, which represents a 66% decline since 2010 [97]. Manipur had the highest AIDS mortality rate, followed by Mizoram and Nagaland, with estimates of 36.86, 28.34, and 26.20 AIDS-related deaths per 100,000 population, respectively [98]. The Government of India has implemented key interventions to achieve UN Sustainable Development Goal 3.3 of ending the HIV/AIDS epidemic by 2030. These include enacting the HIV & AIDS Prevention and Control Act, 2017, and implementing the National AIDS and STD Control Program (NACP) since 1992 [99].

NACO has been playing a crucial role in addressing the HIV/AIDS epidemic in NE India. The organization collaborates closely with state governments, NGOs, and various stakeholders to implement comprehensive prevention, testing and treatment programs in the region. NACO's efforts encompass raising awareness about HIV/AIDS, advocating for behavioural change, facilitating accessible testing and counselling services, and delivering antiretroviral treatment to individuals requiring it. Moreover, NACO strives to combat the stigma and discrimination associated with HIV/AIDS in the NE states of India [100,101]. The CDC has initiated Project Sunshine to implement strategies aimed at enhancing prevention, testing, and treatment options for individuals residing in NE states with the highest prevalence of HIV, namely Manipur, Mizoram, and Nagaland [102].

Conclusion

Infectious diseases continue to pose significant health challenges in NE India, primarily due to its unique geographic, socio-economic factors and sharing international border with four countries. Addressing these challenges requires a multi-faceted approach, including improved healthcare infrastructure, strengthened surveillance systems, enhanced vector control measures, community engagement, cross boarder smuggling and public awareness campaigns and further community-based studies. The region's high burden of tuberculosis highlights the need for strengthening healthcare infrastructure, expanding access to quality diagnostics and treatment, and addressing socio-economic factors that contribute to its prevalence. Japanese encephalitis and waterborne infections require a focus on vaccination programs, mosquito control, and improving sanitation and access to safe drinking water. The prevalence of hepatitis, CHIKV, and scrub typhus emphasizes the importance of surveillance, research, and public awareness campaigns. Collaborative initiatives, such as MERA India and MESA, play a crucial role in malaria control and elimination. To mitigate the burden of infectious diseases in NE India, a comprehensive understanding of the epidemiology, aetiology, and impact of these diseases is necessary.

Further, aid of latest technologies like metaverse may be considered to combat the burden of infectious disease in the region. Metaverse is a combined effort of technologies including AI, AR, VR, IoT, QC and robotics system [103]. The metaverse can enable remote consultations and medical examinations, bridging the gap between patients in remote areas and healthcare providers. With the incorporation of IoT sensors and Artificial Intelligence driven data analytics, real-time disease surveillance and monitoring become possible, enhancing healthcare response and management. Moreover, AR and VR technologies offer valuable tools to train healthcare workers effectively, covering infectious disease prevention, treatment protocols, and emergency procedures. The metaverse also fosters virtual collaboration among healthcare professionals, researchers, and organizations, expediting the development of vaccines, treatments, and medical interventions to combat infectious diseases. Additionally, the utilization of quantum computing allows complex simulations and predictive models, enabling better forecasting of disease outbreaks and evaluation of intervention strategies tailored to the North East region's healthcare needs. It will empower medical practitioners with precision and efficiency while Telemedicine reduces treatment delays. Additionally, the Metaverse may improve patient data security. Despite being in its early stages, it has the potential to transform Indian medical infrastructures, fostering progress and innovation. Collaboration among stakeholders can lead to improved health outcomes in

Northeast India.

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