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Impact of Climate Change on Vector Borne Diseases and Public Health: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Vector-borne diseases endure to contribute knowingly to the global problem of disease, and cause epidemics that disturb health security and cause wider socioeconomic effects around the world. Climate affects by pathogens it causes diseases that spend part of pathogens lifecycle host outside, visible to the environment. The main significant routes of spread of climate sensitive

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diseases are by arthropod (insect and tick) vectors, in food and water. Climate change has the possible to impact the earth's biological systems, The impacts of climate change on health are wide-ranging and diverse. They encompass the rise in fatalities and illnesses caused by more frequent and intense extreme weather events like heatwaves, storms, and floods. Climate change also disrupts food systems, leading to an increase in diseases transmitted through food, water, and vectors. Due to climate change emerging nations with partial resources are expected to face a host of health effects, including vector-borne and water-borne diseases such as cholera, malaria and dengue. Climate change can impact the transmission dynamics, geographical expansion, and recurrence of vector-borne diseases through various channels. These include its direct influence on the pathogens, vectors, non-human hosts, and humans involved. Furthermore, climate change has the potential to modify entire ecosystem habitats, including urban environments, thereby influencing the proliferation or decline of vectors and non-human hosts. This article analyses common and prevalent infectious diseases in India, their links to climate change.

Keywords: Climate change; vector borne diseases; waterborne diseases; public health.

1. INTRODUCTION

“The impact of climate change on vector-borne diseases (VBDs) and the factors contributing to this effect. It emphasizes that human activities, especially the emission of greenhouse gases from burning fossil fuels, are increasing global temperatures, leading to changes in the distribution, seasonality, and incidence of VBDs. Human activities, such as burning fossil fuels, release greenhouse gases (GHGs) like carbon dioxide, methane, and nitrous oxide into the atmosphere. This intensifies the natural greenhouse effect, leading to global warming” [1]. “Vector-Borne Diseases VBDs are caused by parasites, bacteria, and viruses transmitted to humans through arthropod vectors like mosquitoes and ticks” [2]. “VBDs are found worldwide and cause hundreds of millions of cases and over 700,000 deaths annually” [3]. “Rising temperatures influence the physiological traits of pathogens, vectors, and reservoir hosts, affecting the rate of disease spread in susceptible populations” [4]. “Arthropod vectors are particularly sensitive to changes in climate due to their ectothermic nature. Their internal temperature is regulated by external environmental conditions, and their larval development often depends on specific humidity and water conditions” [5]. “Climate change can alter the intensity of disease transmission locally, with yearly patterns varying due to changes in weather patterns. For this reason, and the expectation that climate warming will occur earlier and be more severe toward the poles temperate countries may be those most threatened by emergence and re-emergence of vector-borne diseases. The development and replication of pathogens transmitted within or in the environment also occurs faster at high temperatures” [6]. “The negative impact of infectious diseases on health and well-being is intrinsically linked to a combination of multiple stressors or drivers such as poor sanitation, access to clean water and food, the quality of public health services, political instability and conflict, drug resistance, and animal and/or human population movements” [7]. “Our ability to shape and adapt to the environment is demonstrated by our actions in land use, such as deforestation/afforestation and agricultural activities, as well as the construction of artificial water bodies or dams. These activities play a crucial role in defining and altering the natural landscape” [8] and “the measures undertaken to control infectious diseases such as vaccine and drug development, insecticide spraying, distribution of impregnated bed nets, and development of rapid diagnostic tests, are also critical factors affecting infectious disease transmission. Climate has a direct impact on the dynamics of a subset of infectious diseases, including vector-borne diseases (VBDs), some water-borne diseases such as cholera, and other soil-borne and food-borne pathogens” [9]. Climate change can exacerbate poverty in several ways. Extreme weather events such as hurricanes, floods, and droughts can destroy homes, infrastructure, and agricultural lands, leading to reduced income and livelihood opportunities. Impoverished communities often face challenges in adapting to these changes and have limited resources to recover from such disasters. Climate change-induced environmental changes can contribute to population displacements and migration patterns. As communities face challenges like increased water scarcity, rising sea levels, or agricultural losses, individuals may be forced to migrate to seek better living conditions. This movement of people can lead to overcrowding in certain areas, increasing the risk of VBD transmission. Climate change can strain healthcare systems, particularly in vulnerable regions. The increased frequency and intensity of extreme weather events can overwhelm healthcare infrastructure, disrupt supply chains of medicines, and hinder access to essential healthcare services. Limited healthcare access means fewer resources for early detection, prevention, and treatment of vector-borne diseases. Changing temperatures and precipitation patterns can expand the geographic range of disease-carrying vectors like mosquitoes and ticks. Warmer temperatures can also accelerate the reproduction and transmission rates of these vectors, increasing VBD transmission in previously unaffected areas [10].

2. METHODOLOGY

This brief review was conducted by searching through various databases, such as PubMed, GBIF, and Google Scholar. The review aimed to include relevant studies related to Global Climate Change, Vector-borne Diseases, malaria, dengue, public health. It is important to consider more recent research for a comprehensive understanding of this topic.

2.1 Effects on Transmission of Vector-Borne Diseases

VBDs are human diseases caused by parasites, bacteria and viruses that are spread by vectors. Some diseases will transmit to areas where they are presently absent. For example, Chikungunya, Dengue and Zika Virus Disease are evolving in countries where they were previously unknown. Intensity of transmission of some pathogens will change locally, and yearly patterns will vary with changes in weather patterns. As global temperatures rise due to climate change, several aspects of VBD transmission can be affected. One crucial factor to consider is how changes in temperature and humidity can influence the breeding patterns of disease-carrying mosquitoes. Higher temperatures can expedite the development of mosquito larvae, leading to faster population growth and increased disease transmission rates. Mosquitoes, particularly those spreading diseases like dengue or malaria, rely on stagnant water for breeding. Changes in rainfall patterns may create new breeding sites or affect the availability of suitable habitats for mosquitoes, potentially expanding or shifting their geographic range. increased temperatures could enhance the transmission of diseases like Zika virus, while others indicate a potential decrease in malaria transmission in certain regions due to changes in temperature and rainfall patterns.

2.1.1 Malaria

“Malaria is a deadly disease caused by the Plasmodium parasite and transmitted through the bites of infected female Anopheles mosquitoes. The mosquito larvae (undeveloped stages) are found in various aquatic habitats like marshy areas, slow-moving streams, and still lakes or ponds” [11]. According to the World Malaria Report of 2018, there were approximately 219 million malaria cases and 435,000 deaths recorded in 2017. Several factors contribute to the global resurgence of malaria. These Resistant strains are strains of microorganisms, such as bacteria or viruses, that have developed mechanisms to survive exposure to antimicrobial drugs or other control measures like Antibiotic-resistant bacteria, Antiviral-resistant viruses, The challenges posed by resistant strains include, Spread and transmission, public health impact. Increased temperatures can accelerate the development of certain parasites, such as those causing malaria and dengue fever. Warmer temperatures can shorten the time needed for maturation and reproduction, leading to higher parasite populations. Each mosquito species has an optimal temperature range for successful breeding. For example, the Aedes aegypti mosquito, known for transmitting dengue fever, thrives in temperatures around 25-28°C. Outside this range, mosquito development and breeding may slow down or even cease. Climate change and rising global temperatures could have significant implications for parasite development and mosquito behavior. Increasing temperatures may expand the geographical distribution of mosquitoes, leading to the spread of diseases into new regions. It can also alter the timing and intensity of mosquito breeding seasons. Minor changes in temperature can impact the parasite's survival and the ability of mosquitoes to transmit the disease. “Lower temperatures might reduce transmission strength in endemic areas, leading to higher proportions of the population lacking immunity and potentially causing epidemics in later years. Conversely, at lower temperatures, even a small increase in temperature can significantly increase the risk of malaria transmission due to the proliferation of mosquitoes” [12]. Reducing human exposure to mosquito bites through improved sanitation and

Table 1. Vector borne diseases – pathogens and vectors

Disease	Pathogen	Vector	Transmission
Malaria	*Plasmodium vivax, P. ovale, P. malariae, P. falciparum,*	Anopheles spp. Mosquitoes	Anthroponotic
Dengue	DEN-1,2,3,4 flaviviruses	Aedes aegypti mosquito	Anthroponotic
Encephalitis	*Flavi-alpha- and bunyaviruses*	Culex mosquitoes and ticks	Domestic pigs and wild birds
Kala azar	*Leishmania spp*.	Lutzomyia & Phlebotomus spp. Sandflies	Domestic animals - goat, dog cow, buffalo,

protective measures has been considered a secondary approach. However, while these techniques displaced older methods like quinine, which had prophylactic properties, they did not lead to a complete reduction of the malaria pathogen in the environment [13]. There are multiple methods to control mosquito larvae, and their effectiveness can vary depending on the environment and specific situation, Source Reduction, Larvicides, Habitat Modification, Integrated Vector Management . These fish have been identified as efficient predators of mosquito larvae and can be used to control mosquito breeding in stagnant water bodies. By reducing the number of mosquito larvae, the mosquitofish can help limit the growth of mosquito populations and consequently reduce malaria transmission in specific areas. In conclusion, malaria remains a significant global health challenge, and multiple factors contribute to its spread and resurgence. Effective control measures involve a comprehensive approach that includes vector control, public health infrastructure improvement, and the use of innovative methods like biological control with mosquitofish. Continued research and implementation of integrated strategies are essential to combat malaria and reduce its burden on affected communities.

2.1.2 Dengue

“Dengue is a significant public health concern in many tropical and subtropical regions around the world. Dengue fever is a leading cause of hospitalization and death, especially among young children in endemic countries. The virus responsible for dengue is known as the dengue virus (DENV). It is primarily transmitted to humans through the bites of infected female mosquitoes, primarily Aedes aegypti and Aedes albopictus mosquitoes” [14]. Dengue transmission is influenced by a combination of environmental, socioeconomic, and public health factors. Climate variables such as temperature, rainfall, and humidity can impact the abundance and activity of the Aedes mosquitoes and the replication rates of the dengue virus within them. Changes in these climate variables, which are predicted to occur with climate change, could potentially affect the geographical range and seasonality of dengue transmission [15]. Climate change can alter the suitable habitats for Aedes mosquitoes, expanding their geographical range to regions that were previously unsuitable for their survival. This expansion may introduce dengue to new areas or increase the risk of outbreaks in regions that were previously only marginally affected. Changes in climate patterns can also affect the seasonality of dengue transmission. In regions with distinct wet and dry seasons, increased rainfall can create more breeding sites for mosquitoes, leading to higher transmission rates during the wet season. On the other hand, warmer temperatures might extend the mosquito's activity period, leading to the potential for transmission beyond traditional transmission seasons [16]. Additionally, changes in socioeconomic conditions due to climate-related factors can influence access to healthcare, sanitation, and public health interventions, which could affect dengue transmission dynamics [17]. The impact of future climate change on dengue transmission rates is intricate. While regions experiencing increased rainfall and higher temperatures may anticipate elevated rates of dengue transmission, as mosquitoes thrive in warm and moist conditions, the relationship between climate change and dengue transmission is multifaceted. This indicates that as the temperature increases due to climate change, the conditions become more favourable for the spread of the dengue virus [18]. To combat the impact of climate change on dengue transmission, public health authorities and policymakers may need to consider updating their strategies for disease surveillance, vector control, and public awareness campaigns. This can help communities better prepare and respond to the changing patterns of dengue transmission and mitigate the potential health impacts of this disease in the face of a warming climate. The differential ability of *A. aegypti* and

A. albopictus to survive normally lethal temperatures may influence their roles in future outbreaks.

2.1.3 Chikungunya

Chikungunya is indeed a viral disease that is primarily transmitted by Aedes species mosquitoes, with Aedes aegypti and Aedes albopictus being the main vectors responsible for its transmission. Climate change can indirectly influence the transmission of chikungunya by affecting the geographical distribution and behaviour of the mosquito vectors responsible for its spread. Warmer temperatures and changes in precipitation patterns can create more favorable conditions for mosquito breeding and survival, thereby increasing the potential for disease transmission. Additionally, climate change-related extreme weather events, such as heavy rainfall and flooding, can create temporary breeding sites for mosquitoes, leading to sudden spikes in chikungunya cases in affected areas. Historically, Chikungunya has been predominantly found in tropical climates, particularly in regions of Southeast Asia, Africa, and the Indian subcontinent. However, in the past decade or so, there has been a significant geographic expansion of the disease, with reported cases increasing in various parts of the world. India reported nearly 1.39 million cases of Chikungunya in 2006. This indicates the magnitude of the outbreak in that year, highlighting the impact of the disease on public health in the country [19]. “Chikungunya outbreaks have occurred in various parts of the world, including Asia, Africa, Europe, and the Americas. It is not accurate to say that the first outbreak was in Kolkata in 1963, Rajahmundry, in Andhra Pradesh, Sagar in Madhya Pradesh and Nagpur in Maharashtra. From 2006 onwards, there have been reports of large-scale outbreaks of fever caused by Chikungunya in several regions of India. In 2016, Delhi experienced an epidemic of Chikungunya. Suspected deaths due to Chikungunya and related conditions in senior people were reported by Sir Ganga Ram Hospital and Apollo Hospitals in Delhi” [20].

2.1.4 Kala Azar

“Kala-azar, also known as visceral leishmaniasis, is indeed a parasitic disease caused by the protozoan parasite Leishmania donovani. The disease is transmitted to humans through the bite of infected female sandflies belonging to the Phlebotomus genus, with Phlebotomus argentipes being the primary vector in the Indian subcontinent. Kala-azar is widespread in around 88 tropical and sub-tropical countries, posing a significant public health concern. Approximately 350 million people are living in areas affected by the disease and are at risk of infection. Before the availability of dichlorodiphenyltrichloroethane (DDT), periodic outbreaks of Kala-azar occurred in the eastern Indian states of Assam, Bihar, Jharkhand, and West Bengal, as well as eastern parts of Uttar Pradesh. These outbreaks would last for about 10 years, followed by inter-epidemic periods of 10–15 years. DDT, a powerful insecticide, was used to control the population of sandflies and reduce the transmission of the disease” [21]. Involving local communities in the planning and implementation of kala-azar control programs can lead to more effective strategies. Community leaders, health workers, and volunteers can play a vital role in identifying cases, promoting preventive measures, and ensuring treatment adherence. Public support can facilitate research efforts to develop new diagnostic tools, treatments, and preventive strategies for kala-azar. It can also encourage investment in vaccine development.

2.1.5 Japanese Encephalitis

“Japanese encephalitis (JE), major cause of viral meningo- encephalitis in the world, is caused by a single stranded RNA contagion belonging to the rubric Flavivirus” [22]. It was first described in Japan in 1870s and spread throughout huge corridor of Asia. JE is aboriginal in different corridor of the world substantially Asia extending from Japan to India and Pakistan. Griffiths et al. [23] added that “close to half of the population of the world in 24 countries showed endemicity for JE. Transmission of JE contagion between creatures occurs by Culex mosquitoes throughout eastern and southern Asia and the Pacific border”. “Natural transmission is maintained among wild and domestic catcalls, and gormandizers. The grounds for the spread of JE aren't well- understood, but the dynamic agrarian practices, similar as expansion of irrigation which favours vector proliferation and beast husbandry where creatures serve as force host can be suggested. Spreading of JEV into upland areas has been reported from altitude of over to 3,100 m of Tibet in China” [24]. “In general, laboratory examination of the contagion in mosquito vectors indicates degree of exposure to the complaint, intensity of viral exertion and inheritable variation of JEV in surveyed areas” [25]. “Despite, the vacuity of safe and effective

Table 2. Temperature thresholds (0oC) for pathogens and vectors of major vector borne diseases

Disease	Pathogen	Minimum temp	Maximum temp	Vector	Minimum temp for vector
Malaria	Plasmodium vivax	14.5–15 C	33–39	Anopheles	8–10 (biological activity)
	Plasmodium falciparum	16–19 C	33–39	Anopheles	8–10 (biological activity)
Dengue	Dengue virus	11.9	not known	Aedes	6–10
Schistosomiasis	Cercaria	14.2	>37	Snails (Bulinus and others)	5 (biological activity) 25 ±2 (optimum range)
Lyme disease	Borrelia burdorferi	Not yet determined	Not yet determined	Ixodes ticks	5-8

JE vaccines, JE is still of public health significance in resource constraint aboriginal countries. Thus, case- grounded surveillance should be established in those countries showing high transmission” [25].

2.1.6 Water-borne diseases

“Vibrio cholerae bacteria that causes cholera, is naturally present in the terrain, in particular in littoral and estuarine ecosystems. Rita Colwell devoted her life to studying Vibrio bacteria and their ecosystem. V. cholera, like other species within the rubric, attaches to copepods; the survival of these bacteria and their addition accordingly calculate on plankton population viscosity and environmental variables similar as ocean face temperatures and the input of fresh water. cataracts combined with abnormally warm ocean face temperatures favour cholera outbreaks” [26]. “Critically, the quality of public health services, access to clean water and sanitation, and political stability are introductory factors impacting cholera outbreaks; a high illustration is the recent epidemic in Yemen” [27]. “The emergence of numerous other water- borne conditions is climate sensitive and explosively associated with increases in downfall axes and hurricanes. For illustration, a large cryptosporidium outbreak followed cataracts from the Mississippi in Milwaukee in 1993, and colourful poisons and norovirus spread in Katrina’s wake in Louisiana in 2005” [28]. Typhoid fever: Caused by the bacterium Salmonella typhi, it spreads through contaminated food and water and results in high fever, headache, and gastrointestinal issues. Diarrheal diseases include various infections caused by bacteria like Escherichia coli and parasites like Giardia and Cryptosporidium. They lead to frequent watery bowel movements. Hepatitis A: A viral infection affecting the liver, usually transmitted through water contaminated with the feces of an infected person. Dysentery: Caused by bacteria like Shigella, this disease results in severe diarrhea with blood and mucus. Prevention of waterborne diseases involves ensuring access to clean drinking water, proper sanitation and hygiene practices, and adequate wastewater treatment.

2.1.7 Public health intervention

“Malaria highlights several challenges that can do in the perpetration of acclimatization strategies. After two decades of combined transnational and public investment and harmonious declines in malaria cases and malaria- related deaths, worldwide backing has stagnated; malaria is now resurgent in several countries, owing in part to adding medicine and germicide resistance and, to a lower extent, to service dislocations performing from the coronavirus complaint 2019 epidemic” [29]. “The control of vector- borne conditions is among the major challenges across the world health program. The current fast and unbridled urbanization has boosted the concern in resolving these problems using structured strategic plans which can be designed and enforced at global and original stages. inventions are demanded to keep up with birth and socioeconomic challenges and to insure indifferent access to high- quality treatment in low- and middle- income countries” [30]. “The forestalment of dengue infection relies substantially on community- position mosquito-control programs; the perpetration of similar programs varies according to several factors, including backing and operation” [31]. “Avoidance of the vector niche during the transmission season as a result of public communication has long been an important forestalment strategy for Lyme complaint. colourful particular defensive measures and tick-control strategies have been proposed as approaches to reduce the threat of Lyme complaint, but substantiation of effectiveness is generally lacking" [32]. "Recent research has shown successful outcomes in preventing certain vector-borne diseases through vaccination. Vaccines have proven effective in preventing yellow fever, Japanese encephalitis, and tickborne encephalitis" [33]. However, it is worth noting that vaccines for malaria and dengue [34,35] are still under development and await approval. "It is crucial to consider the most up-to-date research in order to have a comprehensive understanding of this topic. For instance, a previously approved and effective vaccine for Lyme disease was previously withdrawn from the market" [36]. However, a new Lyme disease vaccine is currently undergoing evaluation in a phase 3 trial (ClinicalTrials.gov number NCT05477524). Similarly, a new dengue vaccine has demonstrated promising results in a phase 3 trial and is currently seeking regulatory approval from European authorities (NCT02747927). By keeping abreast of ongoing research and clinical trials, we can stay informed about the progress being made in the field of vector-borne disease prevention.

3. CONCLUSION

The Climate difference has grandiose the Vector Borne conditions in also direction. Vector-borne contagious conditions put an important global burden on public health. For over once many decades pandamics of vector-borne arising diseases were increasing maybe through many driving forces containing socioeconomic, environmental, global warming and climate change. Further and further consciousness should be created for millions about human activities that are increasing GHG levels in the atmosphere and therefore Global Warming. To close out, along with assimilated vector regulator measures for tacking problem of vector-borne diseases it is all important to address issues related to climate change with utmost precedence. Efforts to predict impacts of climate change on vector-borne diseases must continue to drive the development of public health policies and programmes that reduce the impact of emerging and re-emerging vector-borne diseases. Immaculately similar model-grounded assessments of risk should include consideration of climate-dependent and independent factors that directly affect vector-borne disease transmission, and also more distal goods of climate change on vector-borne complaint that may arise due to socioeconomic impacts of climate change on our societies. This may warn for contained fight against arising vector-borne contagious conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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