

Exploring the Increased Risk of Vector-Borne Diseases Driven by Climate Change and Proposing Strategic Solutions to Mitigate the Impact. A Narrative Review

Mohd Radzuan RA^a, Mohidem NA^a

^aPublic Health Unit, Department of Primary Health Care, Faculty of Medicine and Health Sciences, Universiti Sains Islam Malaysia, Negeri Sembilan, Malaysia.

ABSTRACT

Since the middle of the 20th century, human activity has caused Earth's climate to change. The Intergovernmental Panel on Climate Change projects that global temperatures will continue rising in the coming decades, leading to significant environmental and health impacts. This traditional narrative review synthesises evidence from previously published literature to determine the epidemiology of vector-borne diseases caused by climate change, their environmental factors, and solutions to address the issues. The vector-borne diseases, such as West Nile virus, malaria, dengue, Chikungunya, and Zika virus, are related to changing climatic conditions that create favorable environments for the transmission of the disease. The climatic factors include rising temperatures, drought, hurricanes, floods, changes in rainfall patterns, higher relative humidity, and shifts in wind patterns. The findings indicate that climate change not only expands the geographical distribution of vectors such as mosquitoes, ticks, and rodents, but also enhances their breeding and survival rates, leading to increased transmission risks. To mitigate these impacts, this review proposes several strategic solutions, including improved surveillance, adaptation measures, disease risk assessments, mitigation, and public health education.

Keywords

Climate change; global warming; vector-borne disease

Corresponding Author

Dr. Nur Adibah Mohidem
Public Health Unit, Department of Primary Health Care, Faculty of Medicine and Health Sciences, Universiti Sains Islam Malaysia, Negeri Sembilan, Malaysia.
E-mail: nuradibahmohidem@usim.edu.my

Received: 19th November 2025; Accepted: 26th January 2026

Doi:
<https://doi.org/10.31436/10.31436/imjm.v25i04/3121>

INTRODUCTION

Climate change is defined by the National Aeronautics and Space Administration (NASA) as a long-term alteration in the weather patterns that characterise the local, regional, and global climates of Earth.¹ Since the middle of the 20th century, the Earth's climate has changed dramatically because of human activity, particularly from the burning of fossil fuels. The Earth's average surface temperature has increased due to this process, which has raised the atmospheric concentrations of heat-trapping greenhouse gases.²

Based on the data from the Intergovernmental Panel on Climate Change (IPCC), the average global temperature over land and ocean surfaces rose by 0.85°C between 1880 and 2012. According to their prediction, the temperature will rise by an additional 1.5°C by the end of the 21st century compared to 1850.³ Surface air temperatures in Southeast Asia are expected to increase by 2°C by 2060 and possibly by 5°C by 2098.⁴ Figure 1 illustrates the effects of greenhouse gas emissions, showing how they contribute to global warming and changes in natural cover, which in turn influence ocean

climate, storms, precipitation, sea levels, droughts, and related phenomena such as floods, fires, and heatwaves, which adapted from.⁵

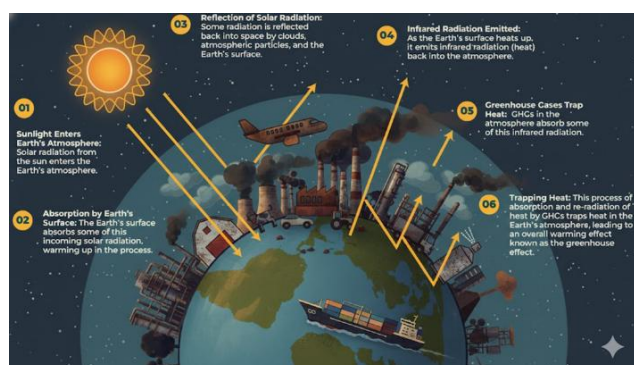


Figure 1: The continuing release of greenhouse gases (GHGs) affects the Earth's system's climatic risks

According to the World Health Organisation (WHO), 24% of all global deaths are attributable to poor environmental conditions annually, mostly owing to climate change.⁶ The ecosystems where diseases, vectors, and hosts interact will be impacted both directly and indirectly by the predicted rise in annual temperatures, altered rainfall patterns, increasing sea levels, and the frequency of extreme weather events.⁷ Infectious microorganisms become more resilient when the environment shifts, thus increasing the frequency and severity of diseases.⁸ Existing studies remain fragmented and often focus on isolated pathogens, targeted regions, or single climatic variables.⁹ Limited integration of climatic drivers, vector ecology, epidemiological trends, and public health strategies, along with inconsistencies in how climate affects disease transmission.¹⁰ An in-depth, comprehensive synthesis that summarises the available data, explains these relationships, and converts scientific findings into practical plans for disease prevention and mitigation is needed. Thus, the purpose of this review is to determine the epidemiology of vector-borne diseases caused by climate change, associated environmental factors, and solutions to address the issues.

MATERIALS AND METHODS

This article is a traditional narrative review to provide an integrative overview of the association between climate change and vector-borne diseases. An extensive literature search was carried out to identify appropriate peer-reviewed articles. It was conducted using the main scientific databases, including PubMed, Scopus, Web of Science, and Google Scholar. Keywords included 'climate change', 'global warming', and 'vector-borne disease'. With a focus on studies addressing epidemiological trends, climatic factors, vector ecology, and mitigation strategies related to climate-sensitive vector-borne diseases, published articles were chosen based on their applicability to this review's objectives. To provide a comprehensive understanding of existing concepts and emerging public health concerns, the chosen studies were critically interpreted and discussed.

VECTOR-BORNE DISEASES CAUSED BY CLIMATE CHANGE

In the previous three decades, the newest disease outbreaks have been either transmitted by vectors or began in animals and then transmitted to people. Vector-borne infections account for more than 17% of all infectious diseases, causing over 700,000 fatalities annually.¹¹ Climate change has a significant impact on arthropod vectors. Pathogens transmitted by mosquitoes and ticks cause vector-borne infections. Due to their distinct biological traits, these two types of vectors will react differently to climate change. Both mosquitoes and ticks are arthropods and ectothermic creatures, which means their surroundings have an impact on the surrounding temperature.¹² Figure 2 illustrates how various weather events can affect vector activity, increase the risk of disease transmission, and impact vector populations. These changes, in turn, affect the spread of vector-borne diseases.

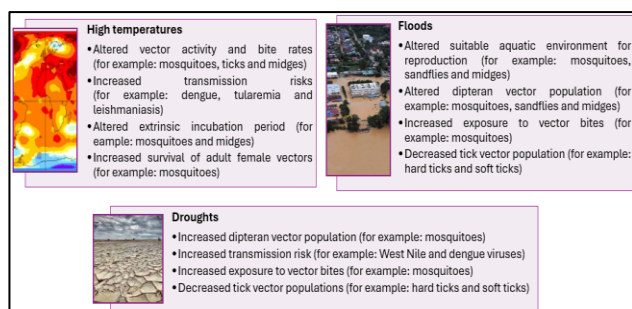


Figure 2: The influence of severe weather events on vectors and vector-borne diseases

One of the most important environmental factors influencing the spread of vector-borne diseases is temperature. Rising temperatures prolong transmission seasons and broaden geographic spread by accelerating mosquito growth, reducing pathogen incubation periods, increasing bite frequency, and improving vector survival.¹³ The increased risk of diseases transmitted by mosquitoes seen under climate change settings is mostly due to these temperature-driven biological interactions.¹⁴

The transmission of vector-borne diseases can be facilitated by international travel, as it brings new vectors to areas with more favorable environmental conditions and can also introduce new pathogens to both native and invasive vector populations.¹⁵ The rate at which pathogens develop and reproduce in mosquitoes is significantly influenced by temperature.¹⁶ People who spend more time outside cleaning up after a hurricane or flood are more vulnerable to mosquito bites. While numerous observational and modelling studies support this association, the magnitude of temperature-related effects varies across regions and vector species, indicating that local ecological conditions play an important modifying role.¹⁷

Vectors have been introduced via trade routes throughout history, with ships playing an essential role in the spread of mosquitoes. These insects were able to adapt in regions with favourable climatic circumstances through their spread.¹⁸ The mosquitoes that act as vectors for spreading mosquito-borne diseases are *Aedes*, *Anopheles*, and *Culex*. These mosquitoes

become carriers of disease-causing germs when they feed on the blood of diseased hosts and then transmit these pathogens to a new host during their next blood meal.¹¹ Several blood-sucking insect species, including the Asian Tiger Mosquito (*Aedes albopictus*), the Stable Fly (*Stomoxys calcitrans*), the Yellow Fever Mosquito (*A. aegypti*), and the Deer Fly (*Chrysops spp.*), contribute to the spread of these diseases.¹⁹

Overwintering can enhance the spread of several species as their development rate rises, notably in Arctic conditions.²⁰ Climate change leads to greater temperatures along altitudinal gradients. Hence, locations with temperate climates and greater altitudes (i.e., upslope) may become more conducive to the spread of diseases by vectors. Since mosquitoes are aquatic insects, the availability of water is essential to their life cycle and larval stage.¹¹ Their biological traits and feeding behaviour are impacted by humidity, which improves vector population dynamics when air humidity levels are high.²¹ During conditions of high humidity, such as during storms, heavy rains, and floods, stagnant water accumulates and provides perfect breeding grounds for mosquitoes.⁴

Mosquito-borne diseases may spread to new areas because of climate change; however, this transmission is also influenced by non-climatic factors such as rapid urbanization, increased population density, global travel, land use change, and socioeconomic inequalities that affect housing quality, sanitation, and access to vector control.²² This occurs when formerly uninhabitable places turn into conducive breeding grounds for mosquitoes that spread the disease.²³ The West Nile virus has expanded to new areas caused by climate change, just like other mosquito-borne illnesses. In 1999, the West Nile virus was initially identified in the United States in New York City, but it has been circulating in Africa since the 1930s.²⁴ In 2010, it led to a major outbreak in Europe that affected nations like Greece, Romania, Hungary, Spain, Russia, Turkey, Italy, France, Portugal, and Serbia. Since then, annual West Nile virus outbreaks have occurred in Eastern and Southern

Europe, suggesting that the virus is still being spread by the expanding mosquito populations.²⁵

In the northern Gulf of Mexico, early-season hurricanes can raise the total yearly number of West Nile Virus by 7.8% and contribute to 94.3% of human neuroinvasive incidence across all locations, enhanced by hurricane damage. *Culex* mosquitoes carry the West Nile virus. Although more than 60% show no symptoms, the infections can pose considerable hazards, particularly for the elderly.²⁶ This mosquito-borne virus can lead to deadly encephalitis in humans, mammals, and birds. Due to increased rainfall and a prolonged mosquito activity season brought on by rising temperatures, the disease's incidence has increased.²¹ The 2010 West Nile virus outbreak was mostly caused by abnormal temperature increases above the monthly average. As temperatures rise, the extrinsic incubation period of the West Nile virus in *Culex* mosquitoes drastically decreases.²⁷

Over the previous 10 years, cases of locally transmitted malaria, dengue, and Chikungunya have been detected in continental Europe.²⁶ The life cycle of dipteran vectors, such as mosquitoes, is relatively short, taking only a few days to complete each stage of development from egg to adult, which can range from a week to several months. These vectors are particularly susceptible to climate fluctuations. Therefore, temperature variations, mostly brought on by global warming, may have an impact on the dynamics of disease transmission, changing the epidemiology of endemic mosquito-borne diseases.²⁸ Global climate suitability for the transmission of dengue has grown by 15.0% for *A. albopictus* and 8.9% for *A. aegypti*, both of which are responsible for spreading the disease.²⁹ The Chikungunya, dengue, and Zika vector *albopictus* has spread throughout the world, including the Mediterranean area and Florida.¹²

The El Niño Southern Oscillation has an impact on the temperature of the sea surface, rainfall, and wind patterns across the Pacific Ocean, which are important factors influencing dengue incidence.³⁰ After Hurricane Mitch in 1998, Central American countries experienced

about 40,000 cases of dengue due to disrupted vector control measures.³¹ A study in Southern Europe emphasizes the potential for future climate conditions to create more susceptible environments for dengue transmission.²⁷ Starting from 2050, climate change is expected to lead to higher temperatures and increased rainfall, which could make certain regions more suitable for the spread of dengue. These regions include southern and western Africa, the southeastern United States of America, northern Argentina, central Mexico, and inland areas of Australia. Meanwhile, coastal towns in eastern China and Japan are anticipated to become more conducive environments to the transmission of dengue by 2050.³²

The Zika virus is mostly transmitted by the bites of infected *Aedes* mosquitoes. It can have serious neurological effects, such as microcephaly in foetuses and, less frequently, Guillain-Barré syndrome, a paralytic autoimmune disease.³³ After a traveller brought the virus to north-eastern Brazil in 2014, the first human case was found in May 2015, sparking an outbreak the same year.³⁴ After that, it expanded to most of the Caribbean and South and Central American nations.²⁷ The Zika virus started to spread widely over the world in the next few years, causing severe outbreaks in South America and circulating in several African and Southeast Asian nations.³⁵ The drought may have caused people to frequently store drinking water in open containers at home, which may have contributed to the outbreak by providing ideal breeding and exposure conditions for disease-carrying vectors.²⁶

Interestingly, vector-borne diseases are regularly affected by extreme weather events. While drought conditions may potentially pose disease risk by encouraging household water storage practices that facilitate mosquito reproduction, flooding events frequently enhance vector populations by creating temporary breeding sites.²⁷ These conflicting mechanisms show that, depending on local infrastructure, water management techniques, and

human behaviour, both excess and scarcity of water may increase the risk of transmission.³⁶

The most prevalent tick-borne disease in temperate Europe is Lyme disease, which is spread by Ixodes ticks carrying bacteria from the *Borrelia* genus.³⁷ The primary vectors of this disease are the Blacklegged Tick (i.e., *Ixodes scapularis*) and Western Blacklegged Tick (*Ixodes pacificus*). The virus that causes numerous cases of tick-borne encephalitis every year in European nations is also spread by these ticks.³⁸ Both Lyme borreliosis and tick-borne encephalitis, which are thought to be the most serious tick-borne diseases in Europe, are mostly spread by *Ixodes Ricinus*.¹² In contrast, *Ixodes scapularis* is the main vector in North America. Figure 3 was adapted from Semenza et al.²⁶ It displays the life cycle of ticks, their interaction with hosts and humans, and how environmental factors such as temperature and humidity could influence tick activity and transmission pathways.

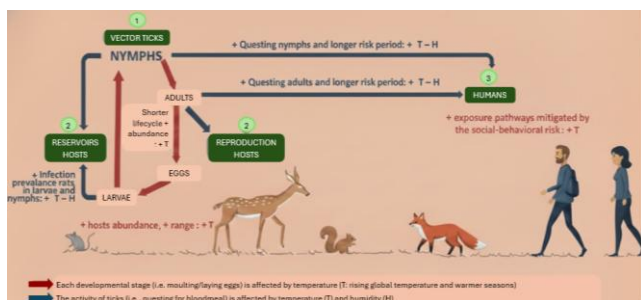


Figure 3: Climatic and meteorological elements that encourage tick life cycles and increase human risk.

Increased tick survival over the winter and an increase in tick populations can result from warmer winter temperatures. In nations like Sweden, Slovakia, and Hungary, moderate winters and warm, humid summers have been linked to a high prevalence of tick-borne diseases.¹² It is noteworthy that the impact of the climate on daily activities may also have an impact on the occurrence of these diseases.¹⁶ People may start outdoor activities early in the spring and continue them into the autumn due to temperature change, coinciding with tick activity. Longer exposure to tick habitats increases the potential of encountering ticks because they are active

from the springtime melting of snow until the autumn return of snow cover.³⁹

A zoonotic disease that is spreading throughout Europe, Russia, and several regions of Asia is tick-borne encephalitis. The yearly incidence rates of tick-borne encephalitis per 100,000 individuals were 2 to 5.4 times higher between 2005 and 2015 than the equivalent national rates.⁴⁰ The European Union recorded 2,057 tick-borne encephalitis cases in 2014. The number of cases reported in endemic areas in Europe has increased by about 400% in the last 30 years; however, this increase can also be linked to better monitoring and diagnosis.¹⁶ According to a study that looked at epidemiological changes in tick-borne encephalitis incidence in the Russian Federation over two decades, Siberia and the Far East are experiencing the biggest changes from 1997 to 2006 and from 2007 to 2016.²⁶

The most prevalent tick-borne disease in the world is Lyme disease. With an estimated 65,000 cases per year, it is often referred to as Lyme borreliosis or tick-borne borreliosis and is the most prevalent common vector-borne disease in the European Union.¹⁶ Erythema migrans rash and non-specific symptoms like headache, fever, exhaustion, and joint and muscle aches are common manifestations. If left untreated, it might escalate to a multisystem disease. Though it is rarely fatal, recent reports have linked deaths to Lyme carditis.³⁹ With a 20% rise in incidence under a 2°C scenario, it is anticipated that the Lyme disease season will spread throughout the United States of America in the upcoming decades. The yearly Lyme disease season is expected to start earlier and last longer because of this increase.¹⁶

Vector-borne disease risk is often shaped by the interaction of socioeconomic and climatic factors. The adverse effects of climate change on health can be worsened by informal settlements, poor drainage systems, inadequate waste management, and limited access to healthcare.⁴¹ Rainfall variability and humidity influence vector breeding through water availability and habitat suitability; however, their effects vary depending

on local infrastructure and human water-use practices.⁴² The significance of social vulnerability in the spread of climate-sensitive diseases is further demonstrated by the fact that equivalent climatic exposures may result in substantially varying disease outcomes among communities.⁴³ Figure 4 provides an overview of five vector-borne diseases, such as West Nile virus, malaria, dengue, Chikungunya, and Zika virus, and how they are impacted by climate change.

Type of vector-borne diseases	Geographic distribution of the disease incidence	Climate change factors that impact the diseases	Examples of animals that enhance the diseases
 West Nile	- In less than 10 years after arriving in New York City in 1999, it spread across all North America, including Mexico and Canada, and entered South America. - It has been detected in all conterminous United States of America, Colombia, and Puerto Rico.	- Higher temperatures - Early spring temperature - Drought in summer - Warm winter - Hurricane and flood	- Primary vectors: Mosquitoes (mainly <i>Culex</i> species) - Primary reservoirs: Birds (especially crows and jays) - Other potential hosts: Horses, humans
 Malaria	- Endemic in 91 countries and territories across the world, mostly in Africa, parts of Asia, and Latin America.	- Increasing temperature - Changes in rainfall patterns - Relative humidity	- Primary vectors: Anopheles mosquitoes - Primary reservoirs: Humans - Other potential hosts: Some primates (for certain <i>Plasmodium</i> species)
 Dengue	- Endemic in more than 100 countries, with the Americas, Southeast Asia, and Western Pacific regions being the most seriously affected.	- Rising temperature - Increased rainfall - Higher relative humidity - El Niño Southern Oscillation effects	- Primary vectors: Aedes mosquitoes (mainly <i>A. aegypti</i> and <i>A. albopictus</i>) - Primary reservoirs: Humans
 Chikungunya	- The outbreaks have been reported in Africa, Asia, the Americas, and Europe. - Major outbreaks have occurred in countries such as India, Indonesia, Myanmar, Maldives, Malaysia, Thailand, France, Italy, Gabon, Republic of Congo, the Central African Republic, Democratic Republic of Congo, Sudan, South Sudan, Kenya, Tanzania, Uganda, Malawi, and Mozambique.	- Temperature rise - Heavy precipitation - Wind pattern	- Primary vectors: Aedes mosquitoes (mainly <i>A. aegypti</i> and <i>A. albopictus</i>) - Primary reservoirs: Humans - Other potential hosts: Monkeys, rodents, birds (in sylvatic cycles)
 Zika	- Major outbreaks have occurred in Brazil, Colombia, El Salvador, French Guiana, Guatemala, Haiti, Honduras, Martinique, Mexico, Panama, Puerto Rico, Suriname, and Venezuela. United States of America.	- High temperature - Severe drought condition	- Primary vectors: Aedes mosquitoes (mainly <i>A. aegypti</i>) - Primary reservoirs: Humans and non-human primates - Other potential hosts: Some rodents and other mammals (in experimental settings)

Figure 4: Climate change impacts on the geographic distribution, transmission mechanisms, and vector ecology of five major vector-borne diseases

Much research relies on ecological or modelling methodologies, which may limit causal inference, despite increasing evidence connecting vector-borne diseases with climate change. Variability in findings can be attributed to differences in study design, data quality, surveillance effectiveness, and regional reporting systems.⁴⁴ These limitations emphasize the need for further multidisciplinary, longitudinal, and standardized research to more accurately measure the links between climate change and vector-borne diseases.

SOLUTIONS TO ADDRESS THE EFFECTS OF CLIMATE CHANGE ON VECTOR-BORNE DISEASE

To detect and control vector-borne disease epidemics, surveillance is crucial. It entails collecting and evaluating information regarding vector-borne diseases. By offering insights into frequency, trends, affected demographics, and geographic distribution, this approach helps in the management and control of the diseases. In addition, it is crucial to adopt a One Health approach that considers the epidemiology of animal infections.⁴⁵ The identification of emerging pathogens, a greater emphasis on vectors, enhanced control for pathogens, and the integration of extensive meteorological data into human and animal epidemiological studies will necessitate an increase in funding, as well as the hiring and training of qualified staff.⁴⁶ Clinicians should receive training from medical schools, residency programs, fellowships, and continuing medical education to anticipate and handle these changing issues.⁴⁷ Furthermore, ENSO forecasts can be included in vector-borne disease prediction models, anticipating El Niño episodes up to two years in advance. It entails creating and adopting practical plans, regulations, and measures to raise public awareness, lower those risks, and enhance readiness, response, and recovery procedures from the effects of climate change.⁴⁸

Moreover, the primary focus of risk assessment should be on potential hazards such as contaminated water sources, inadequate sanitation and cooking facilities, hazardous shelter conditions, population displacement leading to overcrowding, increased exposure to disease vectors, and limited access to healthcare services.⁴⁹ Vaccination can provide direct population-level protection against selected vector-borne infections, thereby reducing disease severity, transmission potential, and outbreak magnitude. However, vaccine availability remains limited for many climate-sensitive diseases, highlighting the continued importance of integrated vector control measures. These include environmental management to reduce breeding sites, use of insecticide-treated materials, biological control approaches, and

community-based interventions.⁵⁰ Optimising scarce resources to counter the global threat of vector-borne diseases requires a deeper comprehension of future vaccination demand, as well as the impact of animal migration and commerce.

CONCLUSION

Understanding the impact of climatic factors on vector-borne disease transmission is essential for developing effective strategies to mitigate risks. Diseases such as West Nile virus, Malaria, Dengue, Chikungunya, and Zika virus are closely linked to rising temperatures, drought, hurricanes, floods, changes in rainfall patterns, increasing temperature, higher relative humidity, and shifts in wind patterns, which affect the survival and development of disease-carrying vectors. To address these challenges, comprehensive surveillance, systematic data analysis, and adaptation strategies are necessary. Evidence from epidemiological and modelling studies demonstrates that integrated vector control strategies, climate-informed surveillance systems, and early warning systems can improve outbreak prediction and reduce transmission risk for vector-borne diseases. Campaigns for community health education are essential for increasing awareness and enabling communities to lower the risks related to vector-borne diseases and climate change. Future research should prioritise longitudinal, region-specific studies that integrate climatic variables, vector ecology, and socioeconomic factors to better quantify causal relationships between climate change and disease transmission. Methodological approaches combining epidemiological surveillance, climate modelling, and One Health frameworks are needed to evaluate the effectiveness of mitigation strategies and support evidence-based public health policy in vulnerable settings.

DECLARATION

Ethics approval and consent to participate are not applicable. This study is a narrative review based exclusively on previously published literature and did not involve human participants or animal subjects.

REFERENCES

1. NASA. What Is Climate Change? [Internet]. NASA Science; c2025 [cited 2026 Jan 31]. Available from: <https://science.nasa.gov/climate-change/what-is-climate-change>
2. Wang L, Wang L, Li Y, Wang J. A century-long analysis of global warming and Earth temperature using a random walk with drift approach. *Decision Analytics Journal* 2023;1;7:100237.
3. Chowdhury FR, Ibrahim QS, Bari MS, et al. The association between temperature, rainfall, and humidity with common climate-sensitive infectious diseases in Bangladesh. *PloS One* 2018;13(6):e0199579.
4. Mora C, McKenzie T, Gaw IM, et al. Over half of known human pathogenic diseases can be aggravated by climate change. *Nature Climate Change* 2022;12(9):869-75.
5. Yap, C (2024). *What are greenhouse gases (GHGs), and how do they cause climate change?* Musim Mas. Available from: <https://www.musimmas.com/resources/blogs/what-are-greenhouse-gases-ghgs-and-how-do-they-cause-climate-change/>
6. WHO. *Environmental health* [Internet]. WHO; 2025 [cited 2026 Jan 31]. Available from: <https://www.who.int/health-topics/environmental-health>
7. Clark SN, Anenberg SC, Brauer M. Global burden of disease from environmental factors. *Annual Review of Public Health* 2025;46(1):233-51.
8. Dennis S, Fisher D. Climate change and infectious diseases: The next 50 years. *Annals of the Academy of Medicine* 2018;47(10):401-4.
9. Nuñez Murillo T, Cadavid Restrepo A, Mayfield HJ, et al. Spatial risk factors of vector-borne diseases in Pacific Island countries and territories: A scoping review. *Tropical Medicine and Infectious Disease* 2025;11(1):6.
10. Borham A, Abdel Motaal K, ElSersawy N, et al. Spatial risk factors of vector-borne diseases in Pacific Island countries and territories: A scoping

-
- review. *Tropical Medicine and Infectious Disease. Climate Change and Zoonotic Disease Outbreaks: Emerging Evidence from Epidemiology and Toxicology. International Journal of Environmental Research and Public Health* 2025;22(6):883.
11. Bartlow AW, Manore C, Xu C, et al. Forecasting zoonotic infectious disease response to climate change: Mosquito vectors and a changing environment. *Veterinary Sciences* 2019;6(2):40.
 12. Edelson PJ, Harold R, Ackelsberg J, et al. Climate change and the epidemiology of infectious diseases in the United States. *Clinical Infectious Diseases* 2023;76(5):950-6.
 13. Ruan W, Liang Y, Sun Z, An X. Climate warming and influenza dynamics: The modulating effects of seasonal temperature increases on epidemic patterns. *NPJ Climate and Atmospheric Science* 2025;8(1):72.
 14. Abbasi E. Climate change and vector-borne disease transmission: The role of insect behavioral and physiological adaptations. *Integrative Organismal Biology* 2025, obaf011.
 15. Ma J, Guo Y, Gao J, et al. Climate change drives the transmission and spread of vector-borne diseases: An ecological perspective. *Biology* 2022;11(11):1628.
 16. Anderson M, Forman R, Mossialos E. Navigating the role of the EU Health Emergency Preparedness and Response Authority (HERA) in Europe and beyond. *The Lancet Regional Health—Europe* 2021;9:100203
 17. Alqassim AY. Differential impacts of extreme weather events on vector-borne disease transmission across urban and rural settings: A scoping review. *InHealthcare* 2025;13(19):2425.
 18. Baker RE, Mahmud AS, Miller IF, et al. Infectious disease in an era of global change. *Nature Reviews Microbiology* 2022;20(4):193-205.
 19. Corley MK, Cosme LV, Armbruster PA, et al. Population structure of the invasive Asian tiger mosquito, *Aedes albopictus*, in Europe. *Ecology and Evolution* 2025;15(3):e71009.
 20. Balaji BN. Insects in a changing climate: A review of distribution patterns, ecological roles and future challenges. *International Journal of Advanced Biochemistry Research* 2024;8(8S):1008-1018.
 21. El-Sayed A, Kamel M. Climatic changes and their role in emergence and re-emergence of diseases. *Environmental Science and Pollution Research* 2020;27(18):22336-52.
 22. Bera B. Mosquito ecology and disease transmission: Implications for global health and vector Control. *UTTAR Pradesh Journal of Zoology* 2025;46(8):64-72.
 23. Hussain S, Nasir Z, Nadeem E, Raza A, Batool M. Dengue mosquito breeding places: A public health concern. *Biological Times* 2025;4(9):12-13.
 24. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. *Annals of the New York Academy of Sciences* 2019;1436(1):157-73.
 25. Dal T, Ramli I, Garaizar J. Effect of climate change on nature and human health with a special focus on infectious diseases in the Mediterranean region. *Journal of Infection in Developing Countries* 2023;17(11):1501-1510.
 26. Semenza JC, Rocklöv J, Ebi KL. Climate change and cascading risks from infectious disease. *Infectious Diseases and Therapy* 2022;11(4):1371-90.
 27. Feng F, Ma Y, Zhao Y. Assessment of global dengue transmission risk under future climate scenarios. *Earth's Future* 2025;13(7):e2025EF006154.
 28. Anikeeva O, Hansen A, Varghese B, et al. The impact of increasing temperatures due to climate change on infectious diseases. *BMJ* 2024;387:e079343
 29. Tong S, Ebi K, Olsen J. Infectious disease, the climate, and the future. *Environmental Epidemiology* 2021;5:e133.
 30. Cai W, Reason C, Mohino E, et al. Climate impacts of the El Niño–Southern Oscillation in Africa. *Nature Reviews Earth & Environment* 2025;6(8):503-20.

31. Tian Y, Xu Y, Liang Y, Zhou Z, et al. Rising dengue risk with increasing El Niño–Southern Oscillation amplitude and teleconnections. *Nature Communications* 2025;16(1):8629.
32. Sang S, Wang Y, Liu Q, et al. Predicting dengue incidence in high-risk areas of China through the integration of Southeast Asian and local meteorological factors. *Ecotoxicology and Environmental Safety* 2025;290:117751.
33. Rabe IB, Hills SL, Haussig JM, et al. A review of the recent epidemiology of Zika virus infection. *The American Journal of Tropical Medicine and Hygiene* 2025;112(5):1026.
34. Lowe R, Barcellos C, Brasil P, et al. The Zika virus epidemic in Brazil: From discovery to future implications. *International Journal of Environmental Research and Public Health* 2018;15(1):96.
35. Noman A, Ramzan K, Aslam A, et al. Comprehensive review on Zika virus: Epidemiology, mode of transmission, treatment, and future perspectives. *Advances in Applied Sciences* 2025;10(1):1-16.
36. Pourzangiabadi M, Najafi H, Fallah A, Goudarzi A, Pouladi I. Dengue virus: Etiology, epidemiology, pathobiology, and developments in diagnosis and control—A comprehensive review. *Infection, Genetics and Evolution* 2025;127:105710.
37. Tsoumani ME, Papailia SI, Papageorgiou EG, Voyiatzaki C. Climate change impacts on the prevalence of tick-borne diseases in Europe. *Environmental Sciences Proceedings* 2023;26(1):18.
38. Pustijanac E, Buršić M, Talapko J, Škrlec I, Meštrović T, Lišnjic D. Tick-borne encephalitis virus: A comprehensive review of transmission, pathogenesis, epidemiology, clinical manifestations, diagnosis, and prevention. *Microorganisms* 2023;11(7):1634.
39. Bouchard C, Dibernardo A, Koffi J, Wood H, Leighton PA, Lindsay LR. Increased risk of tick-borne diseases with climate and environmental changes. *Canada Communicable Disease Report* 2019;45(4):83.
40. Ye RZ, Li YY, Wang XY, Cao WC. Tick-borne viruses: Discovery, clinical aspects, influencing factors and control. *Nature Reviews Microbiology* 2026, 1-19.
41. Hiscox A, Jones RT, Dennehy J, et al. An exploration of current and future vector-borne disease threats and opportunities for change. *Frontiers in Public Health* 2025;13:1585412.
42. Montgomery MJ, Harwood JF, Yougang AP, et al. The effects of urbanization, temperature, and rainfall on *Aedes aegypti* and *Aedes albopictus* mosquito abundance across a broad latitudinal gradient in Central Africa. *Parasites & Vectors* 2025;18(1):135.
43. Newman EA, Feng X, Onland JD, et al. Defining the roles of local precipitation and anthropogenic water sources in driving the abundance of *Aedes aegypti*, an emerging disease vector in urban, arid landscapes. *Scientific Reports* 2024;14(1):2058.
44. Cuervo PF, Artigas P, Lorenzo-Morales J, Bargues MD, Mas-Coma S. Ecological niche modelling approaches: Challenges and applications in vector-borne diseases. *Tropical Medicine and Infectious Disease* 2023;8(4):187.
45. Dunga KE, Okoro CI, Onyenama AC, Ekuma UO, Ohanusi IN, Izah SC. Implementing One Health approach to emerging zoonotic diseases: Bridging surveillance, sustainability and global governance. *Exon* 2025;2(3):200-23.
46. Nwokedi VU, Okafor BC, Agbo OS, et al. One health approach: Integrating human, animal, and environmental health for infectious disease control. *International Journal of Pathogen Research* 2025, 14(3), 123-135.
47. McMahon GT. Accredited continuing medical education delivers: Evidence of value, trust, and impact across the healthcare system. *Journal of CME* 2025;14(1), 2584927.
48. Chen Q, Cui Y, Hong G, et al. Toward long-range ENSO prediction with an explainable deep learning model. *NPJ Climate and Atmospheric Science* 2025, 8(1), 259.

-
49. Bhuller Y, Bancroft X, Deonandan R, Grudniewicz A, Wiles A, & Krewski D. Key attributes of health and environmental risk decision-making: A scoping review. *Risk Analysis* 2025.
 50. May S, Roach M, Maravic M, et al. Understanding the factors that shape vaccination ecosystem resilience: A qualitative assessment of international expert experiences and perspectives. *BMJ Public Health* 2024, 2(1):e000381.