

Feverish Future: Infectious Disease Risks in the Age of Climate Change

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<http://dx.doi.org/10.13005/bbra/3375>

(Received: 04 February 2025; accepted: 09 June 2025)

Significant and long-lasting changes in temperature, precipitation, humidity and air and water quality have a catastrophic impact on human health and increasing rates of morbidity and mortality globally. Through its incessant effects on pathogen or host health, replication, dissemination or migration, climate change can increase the area or duration of time when conditions remain favourable for outbreaks and transmission of emerging or reemerging infectious diseases, irrespective of geographic realm. The primary infectious disease categories that are impacted gravely due to climate extremes are vector-borne infectious diseases and water and food-borne infectious diseases. It is evident from historical trends that contemporary disease patterns and projections for the future that addressing how infectious diseases are impacted by climate change is essential for international health safety and response strategies. Thus, the paper is an attempt to investigate the intricate relationships between climate change and the emergence and spread of infectious diseases, aiming to elucidate how environmental factors, disease vectors and human health outcomes interact amid changing climatic conditions. The findings have ramifications that go beyond current healthcare issues, indicating that in order to reduce future infectious disease outbreaks and improve public health readiness, integrated climate-health policies are pivotal. In short, vulnerable populations are at greater risk and viable global health strategies are crucial to cop up with the unparalleled environmental change.

Keywords: Climate Change, Climate-Sensitive Health Challenges, Emerging Infectious Diseases, Vector-Borne Infections, Zoonotic Diseases.

Climate change and associated disease emergence is one of the most important global issues of the twenty-first century with a cornucopia of impacts.¹ Because infectious diseases have the potential to cause widespread morbidity and mortality, their burgeoning risks associated with extreme weather events, changing precipitation patterns and rising global temperatures have changed ecosystems and the dynamics of pathogen-

host interactions.² All these has made it easier for infectious diseases to arise, resurface and spread geographically at an alarming rate. The relationship between climate change and public health becomes increasingly significant as the planet warms and the weather shifts, particularly with regard to infectious diseases. More incidences of diseases result from improved conditions for pathogens and insects like mosquitoes and ticks brought on by rising

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global temperatures.^{3,4} Moreover, natural disasters and extreme weather can damage healthcare systems, increasing the likelihood of breakouts in communities. It is evident from examining historical trends, contemporary illness patterns and projections for the future that addressing how infectious diseases are impacted by climate change is essential for international health safety and response strategies. It should be noted that changes in the frequency and distribution of vectors and diseases to climate change are also influenced by changes in land use,⁵ the abundance of reservoir hosts⁶ and various control methods adopted.⁷ Furthermore, even while scientific methods to differentiate between human-induced change and natural climate variability are developing, it may be challenging. Notwithstanding these complications, it is evident that the pathogens, vectors, and reservoir hosts that make up vectorborne disease systems are extremely sensitive to the diverse environments in which they live, and that observed variations in the prevalence of vectorborne diseases at particular sites are frequently linked to corresponding shifts in the local climate. Thus, the paper is an attempt to investigate the intricate relationships between climate change and the emergence and spread of infectious diseases, aiming to elucidate how environmental factors, disease vectors and human health outcomes interact amid changing climatic conditions.

Climate change and disease dynamics

The dynamics of infectious diseases are being drastically changed by climate change, which is also changing their prevalence, patterns and effects on the health of humans and animals.⁸ In another study, climate change is a health emergency not only for humans and animals but also for the environment.⁹ The emergence and spread of numerous infections and their vectors are being facilitated by factors such as rising global temperatures, shifting precipitation patterns and an increase in the frequency of extreme weather events. Once restricted to particular areas, diseases are now spreading geographically, presenting new threats to people that were previously untouched. Warmer temperatures and longer mosquito and tick breeding seasons have resulted in notable changes in the spread of vector-borne diseases. Likewise, waterborne diseases also flourish in areas affected by flooding and inadequate sanitation, all of which

are made worse by climate change. Furthermore, as evidenced by the COVID-19 and Nipah virus outbreaks, habitat loss and deforestation are causing changes in ecosystems and biodiversity, which in turn are increasing human susceptibility to zoonotic diseases.¹⁰ Existing public health systems are put to the test by these changing disease patterns, which calls for improved methods of response, prevention and surveillance. In a time of incessant environmental change, it is essential to realize the complex relationships between disease dynamics and climate change in order to mitigate their effects and protect global health.

Temperature and pathogen survival

Many pathogens and vectors reproduce and spread more quickly in warmer climates. Warmer temperatures, for example, prolong the mosquito breeding season, which increases the spread of vector-borne illnesses like dengue, malaria, and the Zika virus. In temperate regions, diseases traditionally confined to tropical areas are now spreading due to warmer winters and longer summers.¹¹

Precipitation and waterborne diseases

Waterborne illnesses like leptospirosis and cholera are more likely to occur when rainfall patterns change.¹² Droughts can concentrate water sources, which encourages the spread of diseases in communities that are water-stressed, while heavy rainfall and flooding can taint drinking water sources with pathogens.

Extreme weather events

Hurricanes, cyclones and heatwaves disrupt infrastructure, displace populations, and create conditions conducive to disease outbreaks.¹³ For example, the aftermath of Hurricane Maria in Puerto Rico saw a surge in leptospirosis cases due to contaminated floodwaters.¹⁴

Ecosystem disruption

Disease vectors and reservoirs proliferate as a result of ecological changes brought on by climate change, which also disturbs predator-prey relationships and affects biodiversity.¹⁵ For instance, habitat loss and deforestation frequently increase human-wildlife contact, raising the possibility of zoonotic spillovers, such as those caused by COVID-19 and the Nipah virus.¹⁶

Emerging and resurging diseases

Diseases that are on the rise pose serious threats to public health systems, economies and

society worldwide with far-reaching ramifications. Diseases classified as emerging occur when they first manifest in a community or when their incidence or geographic range rapidly expands.¹⁷ Conversely, resurging diseases are those that were formerly under control but are now resurfacing as a result of shifting biological, social and environmental factors.¹⁸ Numerous interrelated variables, such as population migration, deforestation, urbanization, globalization, climate change and antibiotic resistance, are responsible for these phenomena.¹⁹ These factors have facilitated the global spread of infectious illnesses, the resurgence of latent infections and the transfer of pathogens from animals to people. The advent of illnesses like COVID-19, SARS, and MERS highlights how zoonotic transmission plays a part in public health emergencies and is frequently connected to changes in land use and close human-wildlife contact.²⁰⁻²³ Similar to this, resurgences of diseases like dengue, malaria and tuberculosis show how disease control strategies are becoming less effective as a result of variables including medicine resistance, climate variability and vector adaptation.²⁴⁻²⁷ As demonstrated by the increased spread of infectious agents through global travel and trade, globalization also makes it easier for viruses to spread quickly.²⁸ These difficulties are made worse by the effects of climate change, which change the habitats and behaviours of vectors and cause diseases like Lyme disease, Zika and chikungunya to spread geographically. Furthermore, the danger of foodborne and waterborne illnesses is increased by urbanization and inadequate sanitation. Additionally, antimicrobial resistance contributes to the return of viral and bacterial infections, making treatment approaches more challenging and raising fatality rates.²⁹ Numerous health risks have emerged and resurfaced as a result of the interaction between infectious illnesses and climate change. In addition to spreading geographically, these illnesses are also changing in intensity and seasonality.

Vector-borne diseases

With millions of cases annually, vector-borne diseases represent serious risks to world health. These illnesses are impacted by a complex interaction of biological, socioeconomic, and environmental factors.³⁰ Diseases have spread geographically and formerly controlled

infections have resurfaced as a result of changes in vector habitats and behaviour brought about by climate change, urbanization, deforestation and international travel.³¹ In tropical and subtropical areas, where vulnerabilities are increased by resource constraints and climatic circumstances, the growing burden of vector-borne diseases is especially severe.³² Environmental changes have a direct impact on the dynamics of vector-borne diseases. Vectors' ability to reproduce and survive is impacted by changing precipitation patterns and rising global temperatures, which allow them to spread their habitats into new areas. As seen by the transcontinental spread of *Aedes aegypti* mosquitoes and the corresponding spike in dengue and Zika outbreaks, the quick speed of international travel and trade also makes it easier for vectors and diseases to spread.³³

Malaria

Rising temperatures in high-altitude regions and changing rainfall patterns have expanded malaria's range into previously unaffected areas, particularly in Africa and South America. Recent studies clearly portrayed the environmental drivers, climate change and emergent diseases transmitted by mosquitoes and their vectors in southern Europe.³⁴

Dengue and Zika

Warmer climates have expanded the range of *Aedes* mosquitoes, the primary vectors for dengue and Zika viruses, into new regions, including parts of Europe and North America. Recent studies highlighted the global expansion and redistribution of *Aedes*-borne virus transmission risk due to climate change.³⁵

Waterborne diseases

Globally, waterborne diseases are worryingly on the rise due to climate change which include cholera, typhoid, hepatitis A, leptospirosis and giardiasis are spread by tainted water sources. As a catalyst, climate change modifies the environment in ways that increase these diseases' ability to survive, proliferate and spread.³⁶ Waterborne infections are becoming a greater hazard to public health globally as a result of favourable conditions for their spread and reemergence brought about by rising global temperatures, shifting precipitation patterns and an increase in extreme weather events. Pathogens like *Vibrio cholerae* multiply more quickly in

warm water bodies due to rising temperatures, especially in coastal and estuarine areas. Similarly, dangerous algal blooms, which release toxins that contaminate drinking water and severely affect aquatic ecosystems, are more common in warmer climates. Sewage mixes with drinking water sources as a result of altered precipitation patterns that are marked by heavy rainfall and flooding, overtaxing water and sanitation systems results in developing hotspots for diseases like leptospirosis and dysentery.³⁷ On the other hand, extended droughts decrease the amount of safe water available, which increases the risk of exposure by concentrating pathogens in limited or stagnant water sources. Extreme weather events like hurricanes, cyclones and typhoons exacerbate the recurrence of waterborne diseases by upsetting infrastructure, uprooting populations and exposing communities to contaminated water supplies.³⁸ Particularly, floods increase the likelihood of outbreaks in both rural and urban regions by acting as a medium for the spread of pathogens.³⁹

Cholera

Warmer ocean temperatures have been linked to *Vibrio cholerae* outbreaks in coastal areas. These bacteria thrive in warmer waters, particularly in regions experiencing increased flooding or water stagnation.

Cryptosporidiosis and Giardiasis

Flooding and inadequate sanitation exacerbate outbreaks of these parasitic infections, especially in low-income and disaster-prone regions. The infectious disease outbreaks in the wake of natural flood disasters along with its global patterns and local implications are well established.⁴⁰

Zoonotic diseases

A major worldwide health concern, especially in light of climate change, is zoonotic diseases, which have a greater impact on pathogens. Through its effects on ecosystems, wildlife behaviour and human-animal interactions, climate change is changing the seasonality, geographic dispersion and modes of transmission of zoonotic diseases, which is contributing to their reappearance.^{41,42} It should be noted that global economy, ecosystems and public health are all seriously at danger from these changes. The habitats and behaviours of wildlife and vectors, including ticks and mosquitoes, which are

important contributors to the spread of zoonotic diseases, are changing as a result of rising global temperatures. In a similar vein, shifting weather patterns are impacting bat and bird migration and mating habits, which raises the risk of zoonotic infection exposure for humans. These dangers are made worse by extreme weather events like droughts and floods, which uproot livestock and wildlife and increase the likelihood of pathogens spreading to human populations. Additional hotspots for virus introduction and amplification are produced by intensive farming methods, wet markets and the illicit wildlife trade.^{43,44} By straining ecosystems and diminishing biodiversity, climate change exacerbates these dynamics by lowering the natural barriers that normally stop the spread of pathogens.⁴⁵ The return of zoonotic diseases emphasizes how closely related human, animal and environmental health.

Lyme Disease

Rising temperatures in North America and Europe have extended the range of Ixodes ticks, the primary vectors of Lyme disease. The disease is termed as “Ticking Bomb” and well-illustrated the impact of climate change on the incidence of the disease.⁴⁶

Hantavirus

Habitat destruction and changes in rodent populations, driven by climate variability have contributed to hantavirus outbreaks. The influence of climatic factors on human hantavirus infections in Latin America and the Caribbean with catastrophic public health impacts.⁴⁷ Several studies reiterated that Hanta virus is an emerging threat for public health.^{48,49}

Fungal Diseases

Climate change is having an increasing impact on the occurrence and severity of fungal illnesses, which have a burgeoning public health impact globally. As opportunistic diseases, fungi flourish in shifting environmental conditions and the changing climate has made it easier for them to proliferate, spread geographically and adapt.⁵⁰ The prevalence of diseases brought on by fungi like *Aspergillus fumigatus*, *Candida auris*, *Cryptococcus neoformans* and *Histoplasma capsulatum* has increased dramatically, endangering the health of people, animals and plants. Their capacity to take advantage of compromised ecosystems, pressures brought on by climate change and environmental

disruptions caused by humans exacerbates the recurrence of fungal diseases. The evolution and adaptability of fungi are directly impacted by rising global temperatures.⁵¹ Once restricted to particular places, many fungal infections are now spreading to new areas and flourishing in climates that were previously uninhabitable.⁵² Because crops are more susceptible to fungal diseases like *Fusarium* and *Puccinia*, these changes also have an impact on agriculture and put food security at risk. Climate change-driven phenomena have also amplified the risk of fungal outbreaks. The resurgence of fungal diseases is further complicated by antimicrobial resistance, which limits treatment options and increases morbidity and mortality rates.⁵³ Many fungi, such as *Candida auris*, are resistant to first-line antifungal drugs, posing significant challenges for healthcare systems. Moreover, the lack of effective vaccines against fungal infections exacerbates the global burden of these diseases, particularly among immunocompromised individuals.

Coccidioidomycosis (Valley Fever)

Warmer and drier conditions in arid regions of the Americas have led to increased cases of this fungal infection. The emergence of valley fever under a changing climate in the United States was well illustrated.⁵⁴ In another study, the dynamics of coccidioidomycosis in relation to climate in the southwestern United States with significant increase in incidences was also observed.⁵⁵

Candida auris

The emergence of *C. auris* as a human pathogen under the auspices of climate change was well established.⁵⁶ The emergence of *C. auris* as a human pathogen have been facilitated by the selective pressure exerted by higher average temperatures brought on by anthropogenic climate change, which favoured strains of the fungi that were acclimated to salinity and higher temperatures, which are similar to those found in the human body.⁵⁷

Vulnerable populations and inequities

Globally, pre-existing social and economic inequities are being exacerbated by climate change, which disproportionately affects vulnerable populations. Vulnerable people are more at risk because of their limited capacity to adapt to the health, economic and environmental effects of a

changing climate. Low-income neighbourhoods, native communities, women, children, the elderly and those with pre-existing medical conditions are some of these groups. The unequal distribution of climate change's effects highlights the connection between structural inequities and environmental deterioration, making it both an environmental disaster and a serious social justice issue.⁵⁸ Natural disasters like hurricanes, floods, droughts and heat waves disproportionately impact marginalized communities. Racism and climate change interaction with disproportionate effects on the lives of minoritised people both within countries and between the Global North and the Global South especially in connection with health and racial justice was also well recorded.^{59,60} These populations lack access to resources necessary for disaster recovery and frequently live in high-risk areas, such as urban heat islands or flood-prone zones.

Furthermore, migration and displacement brought on by climate change increase vulnerabilities since displaced people usually face poor living conditions, limited access to services and increased risks of exploitation. Climate change's economic repercussions make inequality even worse. Vulnerable communities are more likely to rely on climate-sensitive sectors including agriculture, forestry and fishing for their livelihoods. Many people are forced into deeper poverty as a result of extreme weather events and changed rainfall patterns that jeopardize food security and economic stability. Additionally, these groups usually lack the financial and institutional means to implement adaptive measures, which perpetuates cycles of vulnerability and marginalization. Not all infectious diseases are equally affected by climate change. Pre-existing socioeconomic and geographic variables cause vulnerable communities to suffer an unfair burden.

The public health emergency of current global pandemics was well reported⁶¹ with re-emergence of known and future (X) viral pathogens. It is evident that climate change and infectious diseases, especially zoonoses, are tortuously related due to the intricate interplay of ecological disturbances, modified host-pathogen interactions, environmental deterioration and evolving transmission dynamics.⁶² Thus, the world shouldn't expect that the severity of the sickness

in communities who haven't been exposed to infectious diseases before will be the same as in populations where those diseases have been prevalent for a long time.⁶³ It is expected that the next decade will test humanity's ability to balance ecological pressures with health security, making proactive science and equitable healthcare access essential tools in the fight against emerging pathogens.

One Health approach

With its emphasis on the interdependence of environmental, animal and human health, the One Health approach provides a thorough framework for tackling the complex issues brought on by climate change.⁶⁴ Climate change increases hazards in all areas of health by upsetting ecosystems, changing the dynamics of illness and intensifying extreme weather events. The One Health paradigm encourages interdisciplinary cooperation to reduce risks, improve resilience and advance global health security because it acknowledges that these changes cannot be handled in a vacuum. The emergence and spread of diseases, especially zoonotic and vector-borne diseases, are significantly impacted by climate change. The habitats of disease-carrying insects like mosquitoes, ticks and rodents are altered by rising temperatures and changing precipitation patterns, which causes them to spread into new areas and expose previously unaffected populations to diseases like dengue and malaria, dengue, Lyme disease and leptospirosis.

Furthermore, human-wildlife interactions are exacerbated by ecosystem degradation brought on by urbanization, deforestation, and climate-related disasters, which makes it easier for viruses to spread from animals to people. To detect and reduce such hazards, the One Health method offers a framework for integrating environmental evaluation, animal monitoring, and epidemiological surveillance. Antimicrobial resistance and food security are also affected by climate change. The One Health framework guide safe food systems, encourage sustainable farming practices and enhance antibiotic usage monitoring to reduce these hazards. Sanitation and water security risks brought on by climate change can also be addressed *via* the One Health approach. When droughts and flooding degrade water quality, waterborne diseases become more

prevalent with unimaginable health impacts. In addition, the One Health concept emphasizes how crucial international cooperation is in mitigating the effects of climate change. It makes it easier to share information, resources and experience in order to improve health systems and put adaptive measures into place by encouraging collaborations across disciplines and national boundaries. In order to increase resilience to climate-related difficulties, this strategy also places a strong emphasis on community involvement, acknowledging the importance of local knowledge and customs. In short, the One Health approach offers a holistic and integrated framework to tackle the complex interplay between climate change and health. By bridging the gaps between human, animal, and environmental health, it provides a pathway for collaborative, sustainable and equitable solutions to mitigate climate risks and enhance global health outcomes. Adopting the One Health approach is not only a necessity but a moral imperative in safeguarding the health of current and future generations in a rapidly changing world.

CONCLUSION

Climate change is reshaping the landscape of infectious diseases, amplifying existing risks and creating new challenges for global public health. The nexus dynamics of rising temperatures, shifting weather patterns and environmental degradation have enabled the emergence, resurgence and geographic spread of diseases that were once confined to specific regions. Waterborne infections, zoonotic spillovers and vector-borne diseases like dengue and malaria are just a few of the threats to human health and socioeconomic stability brought about by global warming with crippling impacts on life and livelihood. An immediate, multidisciplinary and cooperative effort combining climate research, public health, policymaking and community resilience is needed to address these imminent threats. The challenges posed by climate-driven infectious diseases underscore the need for holistic frameworks, such as the One Health approach, that recognize the interconnectedness of human, animal and environmental health. By addressing the root causes of vulnerability alongside the direct health impacts of climate change, it is possible to build resilience and reduce the global burden of

infectious diseases. Ultimately, the fight against climate-induced infectious disease risks is not only a matter of safeguarding health but also of securing a sustainable and equitable future. The convergence of climate action and public health initiatives presents an unprecedented opportunity to protect ecosystems, strengthen global health security and ensure that the feverish future we face is one of innovation, resilience, and hope, rather than crisis and despair. Future epidemiology, climate science and public health research will be greatly aided by this study on the dangers of infectious diseases brought on by climate change. Emerging infections and changing routes of transmission will necessitate proactive surveillance and predictive modelling as global temperatures rise and ecosystems change. By bridging the gaps between infectious disease dynamics and climatology, this research equips researchers to lessen future health emergencies. Interdisciplinary studies will develop exponentially over the next decade and the work makes sure they are based on solid, useful discoveries for a warming planet.

ACKNOWLEDGEMENT

The authors are thankful to the Department of Biochemistry & industrial Microbiology, Sree Ayyappa College, Eramalikkara, Chengannur, Kerala and the Department of Botany, Nirmala College Muvattupuzha Autonomous, Ernakulam, Kerala for providing their facilities for this study.

Funding Sources

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This research did not involve human participants, animal subjects or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

Author Contribution

Nitha Balan: Conceptualization and Writing Original Draft; Geena George: Analysis, Review & Editing.

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