International Journal of Community Medicine and Public Health
Athirsha A et al. Int J Community Med Public Health. 2024 Nov;11(11):4569-4576
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20243325

Review Article

Unleashing the relationship between climate change and infectious diseases

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Received: 22 August 2024
Revised: 03 October 2024
Accepted: 06 October 2024

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ABSTRACT

Climate change is rapidly emerging as a powerful driver of human health, understanding the relation between infectious disease dynamics and climate change is crucial for public health, particularly in developing nations. This article review delves into the intricate relationship between climate change and infectious diseases, with a particular focus on how climate factors are influencing the spread of vector borne diseases and water borne diseases such as prevalent diseases like malaria, cholera, and dengue in India. The objective is to assess the relationship between climate change and the burden of infectious diseases, with a focus on understanding how climate factors influence the prevalence and spread of infectious diseases. A literature search using PubMed, Science Direct, and government and international health reports focused on the terms 'climate change', 'infectious diseases' and 'health impact'. The review highlights that climate change accelerates vector lifecycles and creates favourable conditions for pathogens, leading to more frequent and severe outbreaks. Extreme weather events are worsening these risks, leading to more frequent and severe outbreaks. This poses a growing threat to global health, particularly in vulnerable regions like India. Despite government efforts, significant challenges remain. Strengthening healthcare infrastructure, improving disease surveillance, and adopting climate-resilient practices are essential to safeguard vulnerable populations and mitigate the impact of climate change on public health.

Keywords: Climate change, Health impact, Infectious disease, Public health

INTRODUCTION

As climate change accelerates, its impact on global health, especially infectious diseases, becomes more pronounced. Rising temperatures, shifting precipitation patterns, and extreme weather events such as storms, heatwaves, floods and wildfires are linked to increased health risks. These changes elevate the prevalence and spread of infectious diseases and pose significant threats to human health, leading to higher mortality, non-communicable diseases, and health emergencies.[1] The impact of climate change on health is both direct and indirect, influenced by environmental, social and public health determinants. Key risks include extreme weather, heatwaves, sea level rise, air pollution, altered vector distribution, water scarcity and reduced food production, contributing to various health outcomes, including injuries and mortality from extreme weather events, respiratory illnesses, waterborne diseases, zoonosis, vector-borne diseases, malnutrition, foodborne diseases, non-communicable diseases (NCDs) and mental health issues. Between 2030 and 2050, climate change could lead to around 250,000 additional deaths annually, primarily due to issues like undernutrition, malaria, diarrhoea and heat stress alone.[2]

The International panel on climate change's sixth assessment report (AR6) reveals that 3.6 billion people already live in areas highly vulnerable to climate change.[3] The World Health Organization (WHO) reports that

climate change is responsible for at least 150,000 deaths per year, a number that is expected to double by 2030.[4] The World Meteorological Organization (WMO) discloses a grim reality, reporting a substantial death toll of 2 million, with a staggering 90% occurring in developing countries. In Asia, 3,612 climate-related disasters have resulted in 984,263 deaths, constituting 47% of the global toll. Notably, India stands out, reporting the second-highest number of deaths attributed to climate change from 1970 to 2021.[5]

Recent research attributes 37% of heat-related deaths to human-induced climate change. Heat-related deaths among those over 65 have risen by 70% in two decades. In 2020, 98 million more experienced food insecurity compared to the 1981-2010 average. The climate crisis threatens to undo the last 50 years of progress in development, global health and poverty reduction, and to further widen existing health inequalities between and within populations.[6] A 2022 study found that climatic hazards have exacerbated 58% of infectious diseases faced globally, affecting 218 out of 375 diseases.[7]

The alarming impact of climate change is evident in the rising death toll and global disparities highlighted by recent reports. Climate change has the potential to disrupt biological systems and significantly impact human health, with infectious diseases emerging as a particularly acute threat. Although the specifics of these effects are not yet fully understood, it is clear that climate change intensifies the severity of infectious diseases, which pose a more immediate risk compared to non-infectious conditions.

Understanding the relationship between climate change and infectious diseases is essential for addressing these escalating global health challenges, especially in developing nations. Shifting climate patterns exacerbate the spread and dynamics of vector-borne, waterborne, foodborne, and respiratory diseases such as malaria, cholera, and dengue.

This review aims to elucidate how climate factors affect these infectious diseases and to highlight the serious challenges posed by climate change in India, underscoring the need for comprehensive public health strategies and preventive measures. To assess the relationship between climate change and the burden of infectious diseases, with a focus on understanding how climate factors influence the prevalence and spread of infectious diseases.

Research articles were sourced from PubMed and ScienceDirect using terms like "infectious diseases", "vector-borne", "waterborne", "foodborne", "airborne diseases", "climate change", "global warming", "temperature", "heat wave" and "flooding." Disease-specific searches by pathogen name were also conducted, utilizing relevant keywords and MeSH terms. A special focus was given to English language publications, focusing on those exploring the relationship between climate change and infectious diseases. Research reports from international organizations and gray literature were included as well.

HEATH IMPACT ON EXTREME WEATHER EVENTS

Extreme Weather extreme events are often short-lived and include heat waves, freezes, heavy downpours, tornadoes, tropical cyclones and floods. Climate-related extreme events either persist longer than weather events or emerge from the accumulation of weather or climate events that persist over a longer period of time.[8] Hurricanes and coastal storms can cause injuries from debris and increase the spread of hazardous chemicals and pathogens through facility damage, storm surge, and flooding. Flooding and sea level rise may contaminate water with harmful bacteria and viruses, leading to foodborne and waterborne illnesses. Wildfire smoke can harm respiratory and cardiovascular health, while extreme heat can cause heat exhaustion, cramps, stroke, and increase the risk of heat-related deaths, particularly for those with pre-existing health conditions.[9]

When floodwaters recede from indoor spaces can lead to mold growth, worsening indoor air quality. Mold spores may cause headaches, irritation, and exacerbate lung diseases like asthma, especially in vulnerable groups such as children, pregnant women, the elderly, and those with pre-existing conditions. Individuals living in poverty, near contaminated sites, or in areas with limited healthcare are at higher risk from extreme weather impacts.[10,11] The below table despites that some examples of extreme weather event resulting infectious diseases outbreak in India.

Climate change can contribute to a global increase in the burden of infectious diseases. Both the number of geographical areas as well as the number of yearly days that are suitable for transmission of certain infectious diseases can increase due to global warming.[12] Certain groups, such as women, children, ethnic minorities, and poor communities, face heightened health risks from climate change.[2] Outdoor workers are at greater risk of heat-related illnesses and accidents, impacting productivity. Vulnerable populations, including the elderly and indigenous communities, are disproportionately affected. Climate-related displacement also exacerbates mental health issues and stress. Predicting the full range of climate impacts on health remains challenging.[6]

CLIMATE CHANGE AND VECTOR-BORNE DISEASES

Vector-borne diseases such as malaria, dengue, Zika, and Lyme disease are expanding into new regions as climate change drives the spread of disease vectors like mosquitoes and ticks. Climate change has increased the risk of nearly 60% of known infectious diseases, including vector-borne and food- and waterborne infections. These emerging and re-emerging diseases present a significant global health challenge.[7]

Table 1: Selected example of extreme weather event resulting infectious diseases outbreak in India.

Climate change hazard	Vulnerability and cascading event	Infectious disease outbreak prevalence.	Reference
Tsunami	Displacement and healthcare disruption. Low immunization coverage.	Measles: 101 cases reported.	Mohan A et al (Tamil Nadu, India)2004–2005[51]
Elevated temperature and rainfall	Increased bacterial concentration in urban and flood-contaminated water.	Cholera Endemic (Vibrio cholerae): 2,479 confirmed cases recorded between 1999 and 2019.	Shackleton et al (Kolkata, India)[52]
Tropical Cyclone	Altering vector survival, activity, and pathogen development and expanded transmission zones.	The 2004 Malaria outbreak in India saw the highest incidence, with 1,915,363 cases reported, while the most recent data shows 176,522 cases in 2022.	Bhattacharya et al (India) [53]
Heavy rainfall	Water Contamination from flood in drain flooding and house flooding and poor faecal sludge management	Enteric infection diseases: 79% of diarrheal stool specimens tested positive in 230 children	Berendes et al (Vellore, India)[54] NVBDCP [17]
Flood	Contaminated water	Diarrhoea, enteric and respiratory infections	Biswas et al (West Bengal, India)[55] Mondal et al (West Bengal, India)[56]
Cyclone, heavy rainfall and flooding	widespread infection, water contamination inadequate sanitation, and strain on healthcare systems.	Leptospirosis outbreak: 18 cases in Mumbai;14.1% of population affected and, 9 fetal cases recorded in Odisha.	WHO (Orrisa, India 2002)[57] Karande et al (Mumbai, India)[58]
Drought and water availability	Water scarcity, poor sanitation and contaminated water combined with weather fluctuations, extreme monsoon flooding, and altered mosquito breeding patterns.	Acute diarrheal diseses: 813, 343 cases, 12 deaths (Maharashtra); Typhoid: 94,363 cases; Malaria: 122 infants affected, 47 deaths (Rajasthan)	Dias et al (Maharashtra, India)[59] Mathur et al (Rajasthan, India)[60]

The geographical expansion of insect vectors, like Aedes albopictus, poses a major threat by transmitting over 22 arboviruses, including dengue, yellow fever, and West Nile virus, as well as parasitic diseases like Dirofilarial nematodes. This emerging risk should not be underestimated and cholera is highly temperature dependent disease which increase with the increase in water temperature.[13,14] Malaria caused by five Plasmodium species and transmitted by Anopheles mosquitoes remains a significant global health issue.[15] In 2022, 249 million cases were recorded, with India accounting for 66% of cases in the WHO South-East Asia Region.[16] Despite a decline in India's malaria cases from 2.09 million in 2001 to 0.12 million in 2022, climate change is emerging as a key driver of malaria transmission.[17] Malaria transmission is strongly influenced by environmental factors like climate, rainfall, and topography. Tropical regions with warm temperature, heavy rainfall, high humidity and low altitudes are ideal for mosquito breeding, longevity and parasite sporogonial.[18] Climate change is expected to expand the spatial spread of Plasmodium vivax and Plasmodium falciparum malaria, increasing transmission windows and shifting transmission months. By the 2030s, some regions may face unstable malaria and heightened outbreak risks due to these climate-induced changes.[19] Dengue caused by the dengue virus (DENV, serotypes 1-4), is a significant global health threat, particularly in tropical and subtropical regions.[20] Over the past decade, dengue cases in India have risen, with over 5 million cases and 5,000 deaths reported from 86 countries/territories globally in 2023.[21] India alone recorded 289,235 cases and 485 deaths this year.[22] The disease, driven by complex interactions among host, vector, and virus, From the trend it can be evident that a continuous transmission of the disease since the 1950s, aggravated by urbanization, globalization and unsuccessful vector control ending in increased infection and transmission of the virus.[23]

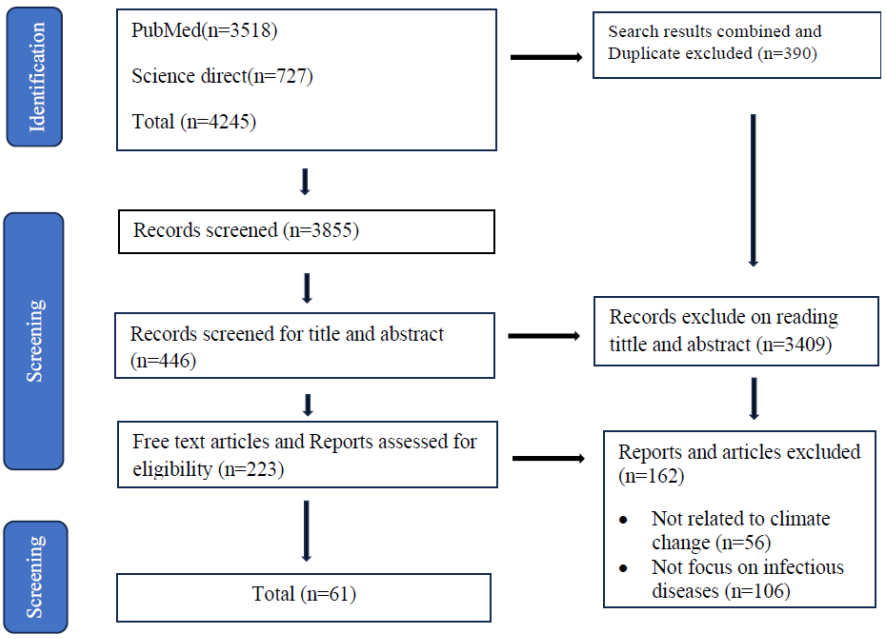

Figure 1: The process by which articles were selected or rejected for inclusion in the study.

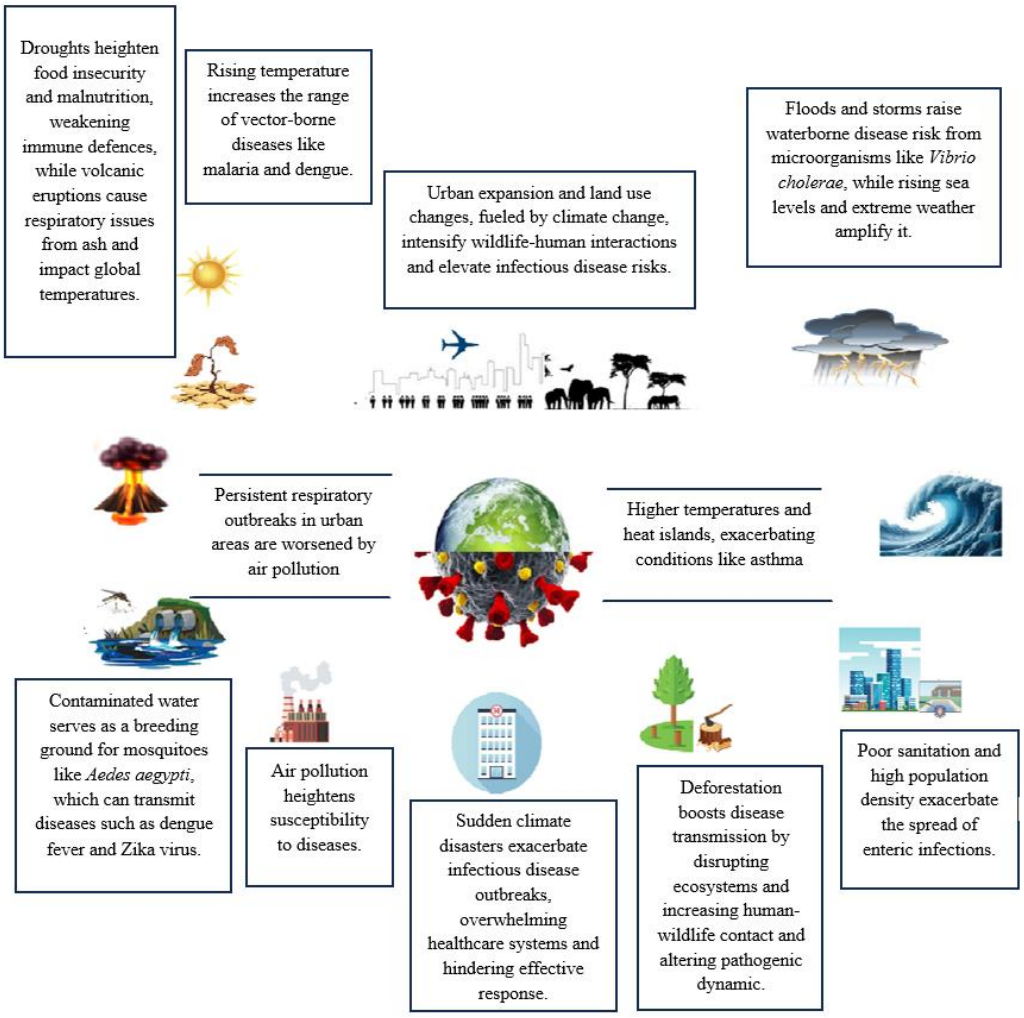

Figure 2: A complex interplay between climate change and infectious diseases.

Japanese encephalitis (JE) is a major cause of viral meningoencephalitis, caused by a Flavivirus RNA virus.[24] JEV is the is a leading cause of viral encephalitis in Asia, with nearly 68,000 cases and 13,600 to 20,400 deaths globally each year. Major outbreaks occur every 2-15 years, intensifying during the rainy season when vector populations increase.[25] In 2023, India reported 1,107 JE cases and 65 deaths.[26] Climate change, particularly rising temperatures, is a major global concern impacting pathogen-vector-host relationships. Lice, fleas, ticks, and mosquitoes are key vectors for public health diseases.[27] Tropical and subtropical climates, which support diverse species, often bear the burden of parasitic diseases due to their conducive environment.[28]

Changes in temperature, precipitation, and humidity impact the distribution of insect vectors, altering the range, period, and intensity of infectious diseases.[29] Climate change affects these vectors, leading to increased agricultural pests, diseases, and disease vectors. Rapid climate shifts have long-term effects on humans and ecosystems, exacerbating vector-borne diseases.[30]

IMPACT ON WATER AND FOOD BORNE DISEASE

Water-borne diseases (WBDs) like cholera, typhoid, hepatitis A and E, and diarrhoea are major public health issues worldwide, especially in developing countries.[31] Climate disasters like droughts and floods cause direct injuries and fatalities, and indirectly affect health by reducing food production and impacting nutrition levels.[32] Climate change is changing precipitation patterns, causing rising sea levels, and altering seawater salinity, whilst also impacting several factors such as surface water temperature and the reproduction, survival, and sustenance of viruses and bacteria in waterbodies, which consequently affects human health.[33]

According to WHO, 2 billion people lack safe water, and 600 million face foodborne illnesses yearly, with children under 5 making up 30% of fatalities. Climate change increases risks of waterborne and foodborne diseases. In 2020, 770 million people, mainly in Africa and Asia, faced hunger due to disruptions in food availability and quality.[34]

Cholera and typhoid, bacterial waterborne diseases, are strongly linked to temperature increases. Each 1°C rise in global temperature boosts Salmonella infections by 5-10%.[35] Climate change exacerbates waterborne disease risks due to inadequate clean drinking water, especially heavy rainfall heavy rainfall, and high temperatures, increasing diarrheal diseases.[31,36] Children are especially vulnerable due to weaker immune systems.[37] Severe climate changes heighten the prevalence of pathogens like Vibrio cholera. Understanding how climate change affects waterborne diseases is crucial for assessing its impact on human health, particularly in ASEAN countries. Identifying the effects of climate change on WBDs (not only cholera and typhoid) is the first stage of assessing climate change impacts on human health.[38] According to the World Health Organization, 1.1 billion individuals consume water that is moderately polluted by faces, and 1.8 billion people die per year from diarrhoea, a WBD.[39,40] A warmer climate could cause water-borne diseases to become more frequent, including cholera and diarrhoeal diseases such as giardiasis, salmonellosis, and cryptosporidiosis.[41] Diarrhoeal diseases are already a major cause of morbidity and mortality in South Asia, particularly among children. It is estimated that one-quarter of childhood deaths in South Asia are due to diarrhoeal diseases.[42] Cryptosporidium is the second major cause of moderate to severe diarrhoea in children younger than two and an important cause of mortality worldwide. It occurs most commonly during waterborne epidemics and in immunocompromised hosts.[43]

Extreme weather can increase the concentration of oocysts, and heavy rainfall may cause the outbreak of cryptosporidiosis.[44] V. cholera is naturally present in the environment and is autochthonous in riverine, coastal, and estuarine ecosystems.[45] Interaction between vibrios and copepods are affected by environmental variables. salinity of 15% and temperatures ranging from 25°C to 30°C have been shown to be important in influencing the attachment of V. cholera to copepods.[46] Cholera is a well-known water-borne diarrhoeal disease that has afflicted humankind since ancient times. Outbreaks of cholera have occurred in India, Bangladesh, and more recently, Latin America and Africa.[47]

CLIMATE CHANGE AND RESPIRATORY DISEASE

Climate change exacerbates respiratory diseases by increasing exposure to harmful aeroallergens and air pollutants. Particulate matter (PM), ozone (O3), nitrogen dioxide (NO2), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) are key contributors. Fine particles smaller than 2.5 micrometres pose the greatest health risk as they can penetrate deep into the lungs and even enter the bloodstream.[48] Pollen from grass, weeds, and trees worsens hay fever, asthma, and viral infections, while extreme weather and wildfires elevate air pollution and respiratory risks.

Spikes in ground-level ozone increase hospitalizations for COPD, pneumonia, and other lung issues, and are linked to premature deaths and low birth weight.[49] Higher air pollution levels lead to a range of respiratory issues, including coughing, wheezing, decreased lung function, airway inflammation, and bronchial hyperactivity. It increases respiratory infections, emergency visits, hospitalizations, and the risk of asthma, especially in children. Long-term exposure can result in chronic lung function loss and premature mortality in those with chronic lung disease.[50]

CONCLUSION

In alignment with SDG Goal 13, which urges urgent action to combat climate change, the Government of India has implemented key policies such as the National Action Plan on Climate Change (NAPCC), the National Mission on Strategic Knowledge for Climate Change (NMSKCC), and the Global Health Security Agenda (GHSA). These initiatives focus on strengthening climate science, improving water efficiency, and integrating health and climate strategies. Additionally, India's efforts are aligned with global mandates like the Paris Agreement, while reinforcing Early Warning Systems (EWS) to enhance preparedness. However, despite these actions, the government anticipates an increased burden from climate-induced crises and infectious disease outbreaks This article underscores the critical links between climate events and infectious diseases in India, calling for stronger strategies to mitigate future risks. To address the evolving challenges posed by climate change on public health, more robust action is needed, including enhanced global cooperation, equitable policies, and proactive, climate-resilient measures to ensure a safer, more sustainable future.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Athirsha A, Anitha M, Sundar JS, Kalpana S,Valarmathi S, Srinivas G. Unleashing the relationship between climate change and infectious diseases. Int J Community Med Public Health 2024;11:4569-76.