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REVIEW ARTICLE

Climate Change, Extreme Weather Events and Infectious Disease risk: A Narrative Review Focusing on India

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ABSTRACT

Climate change is one of the biggest imminent threats the world faces in the current century. There is a growing risk of emerging diseases secondary to climate change and the magnitude of this risk is likely underestimated. The current review aims to summarize the mechanisms of climate change impact on infectious diseases, and interventions to manage this growing problem in India.

Climate change disrupts ecosystems and impacts disease transmission through several distinct pathways, each influenced by environmental shifts. Extreme weather acts as a catalyst by increasing the spread of climate sensitive infectious disease. There have been several disease outbreaks in India linked directly to climate-related events, highlighting the critical connection between environmental changes and public health.

Addressing climate change induced infectious disease calls for multipronged and interdisciplinary action to safeguard human and animal health, strengthen disaster resilience and advance climate action. The complex interplay of environment, human health and animal health in the pathogenesis of this problem requires a One Health approach to balance the health of human and animal populations and ecosystems. Climate-informed disease surveillance and early warning systems, strengthening health systems to become more climate-resilient, hazard awareness generation and risk communication, infrastructure planning to minimize climate driven displacement, animal surveillance and cross sectoral antimicrobial resistance surveillance, conservation of wildlife habitats and ecosystems, water, sanitation

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and hygiene services resilient to climate change, resettlement of populations at-risk of climate induced disasters and climate change mitigation actions can help achieve the Sustainable Development Goals for human health and climate action.

KEYWORDS

• Infectious Disease • Communicable Disease • Climate Change • Extreme Weather Event • Climate Resilience • One Health

INTRODUCTION

Climate change is one of the biggest imminent threats the world faces in the current century. With shifting climate patterns, there has been a rise in extreme weather events across the globe.[1] Climate change due to global warming has been attributed to the increase the likelihood, frequency and severity of extreme weather events.[2] Extreme weather events are meteorological phenomena or events which are rare at a particular place and time of the year compared to historical climate records and lie in the highest or lowest 10% of historical measurements. They include but are not limited to heavy rainfall and flooding, heat wave, tropical cyclones, drought, wildfires and severe storms. Global warming has been predicted to continue, thereby increasing regional variations in extreme weather patterns.[3] From 1993 to 2022, India faced more than four hundred extreme weather events resulting in at least 80,000 fatalities. Globally, over 765000 deaths occurred from 9400+ extreme weather events during the period.[4]

Apart from direct impact, these meteorological events also pose a risk of increase in the occurrence and spread of infectious diseases. Evidence shows that out of all infectious diseases reported to have impacted humans globally, 58% were aggravated by climate hazards at some point due to change in disease transmission patterns.[5] Outbreaks of gastrointestinal illnesses, vector-borne diseases and rodent-borne infections have been reported following events of floods and cyclones in India.[6] Additionally, climate change is suspected to indirectly contribute to antimicrobial resistance further compounding to the problem of rising infectious diseases.[7] There is a growing risk of emerging diseases secondary to climate change and the magnitude of this risk is likely underestimated.[8]

Tackling this threat requires a complex multispectral approach including strengthening infectious disease control systems along with climate action. The current review aims to summarize the causes and mechanisms explaining the link between climate change and infectious diseases, and interventions to manage this growing problem in India.

MECHANISMS LINKING CLIMATE CHANGE AND EXTREME WEATHER EVENTS TO INFECTIOUS DISEASE RISK

Extreme weather acts as a catalyst by increasing the risk and spread of climate sensitive infectious disease. There have been several disease outbreaks in the country linked directly to climate-related events, highlighting the critical connection between environmental changes and public health. These events included heavy rainfall, heatwaves, floods and droughts, creating conditions favourable for disease transmission. Heavy rainfall and floods compromise water treatment, distribution and sanitation systems, creates hotspots for vector breeding, displaces human and animal populations and reduces access to healthcare, thus increasing the likelihood of waterborne and zoonotic diseases.[9] While droughts contributed to the spread of infectious diseases due to multiple factors like water scarcity and behavioural changes in humans and animals, such as reduced access to safe drinking water forces reliance on contaminated sources like stagnant ponds and rivers, leading to outbreaks of cholera, typhoid, and diarrheal diseases, limited water also hampers sanitation and hygiene, increasing transmission risks. In extreme cases due to crop and livestock losses result in migration of people to crowded areas or relief camps, where poor sanitation and strained health services may facilitate disease spread.[10] Additionally, animals gathering near human settlements in search of water raise the risk of zoonotic infections. Changing climatic conditions along with extreme weather events increases the duration and geographical area over which conditions remain favourable for infectious disease transmission.[11] Climate change disrupts ecosystems, bringing wildlife and their pathogens into closer contact with human populations. It impacts disease transmission through several distinct pathways, each influenced by environmental shifts. These mechanisms have been discussed below.

- **Vector-borne diseases:** Rising temperatures worsen the transmission of vector-borne diseases through several interconnected biological and ecological mechanisms. Higher ambient temperatures accelerate the life cycle of vectors like mosquitoes, causing them to mature from larvae to adults more rapidly and leading to a significant increase in their overall population. Warmer climates also affect biting patterns and overall survival rates of vectors, thereby increasing disease transmission.[12] Furthermore, for a range of mosquito-borne pathogens the warmer conditions shorten the extrinsic incubation period, allowing the mosquito to transmit the disease sooner and infect more individuals during its lifetime.[13] Increased temperatures boost the mosquito's metabolic rate, hence they are driven to engage in hematophagy more frequently thereby increasing the rate of potential disease transmission with each bite. The effect of climate change is not restricted to mosquitoes but also extend to other vectors of infectious disease such as ticks and sand-fly. Climate change leading to increased temperatures, high humidity and changes in rainfall pattern favours the geographical expansion of ticks through expansion in tick density and diversity, increased prevalence of tick reservoir hosts and reservoir animal migration to human habitats.[14] Increase in rainfall and humidity have been linked to rising sand-fly populations.[15]
- **Gastrointestinal diseases:** Flooding provides a potent environment for the spread of gastrointestinal diseases. The primary mechanism is the widespread contamination of water sources with infectious pathogens. Floodwaters mix with human and animal faces, overwhelming sewage systems and contaminating drinking water supplies. This creates a direct and efficient pathway for the faecal-oral transmission of pathogens, such as Vibrio cholera, norovirus, Salmonella and Campylobacter.[16,17] Temperature can also impact the life cycle of pathogens indirectly through influencing their environment and habitat. For example, warmer climate can provide a more suitable environment for the reproduction and growth of some pathogens such as Vibrio and Salmonella.[18] Indirect mechanisms such as altered gut microbiota composition and diversity as a result of climate change increases susceptibility to gastrointestinal illnesses.[19] Global warming is also impacting global food chains and trade and increasing the probability of pathogen transmission.[20]
- **Air-borne Infections:** The prevalence and transmission of airborne infections is affected by changes in temperature and humidity, which can influence the survival of viruses and bacteria in the air, potentially expanding the seasons for respiratory illness.[21] Factors such as dust storms, which are gaining in frequency and severity in dry regions due to desertification, can transport fungal spores and bacterial pathogens over vast distances.[22] Additionally, extreme weather events like hurricanes and cyclones can lead to the release of fungal spores from decaying vegetation and damp environments, causing respiratory infections. Temperature fluctuations and change in humidity and precipitation, compounded with air pollution, has increased the risk of respiratory infections, with young children and elderly population being most susceptible.[23] Extreme weather events are reported to be associated with outbreaks of viral respiratory illnesses through increased virus viability, replication and transmission, impaired human respiratory immunity, population movement and overcrowding.[24]
- **Zoonotic disease:** Zoonotic diseases are transmitted between vertebrate animals and humans, through direct contact or indirect spread by arthropod vectors.[25] Several zoonotic diseases are significantly impacted by extreme weather events as these disruptions change animal movement and behaviour, increasing human-animal interaction and the

chances of pathogens crossing between species. For example, water sources can get contaminated with rodent waste after heavy rainfall and flooding, leading to outbreaks of diseases like leptospirosis.[26] Heavy rainfall and heatwaves can increase rodent population and human-rodent interaction, as well as increase in Yersinia pestis pathogen inside the reservoir host, and increased plague risk.[27]

- **Pandemic threats:** Apart from the above, climate change might be paving the way for more serious threats to human health. First, there has been an observed change in fungal epidemiology including increased virulence and potency, altered geographical distribution of fungal pathogens and emergence of new invasive fungi.[28] There has been an increase in adaptation and populations of pathogenic fungi as well as susceptibility of humans to fungal infections because of climate change and associated anthropogenic factors.[29,30] It has been suggested that climate change can increase risk of human exposure to fungal pathogens and cause a pandemic.[31] Second, climate change explains to an extent the rapid increase in antimicrobial resistance. Mechanisms linking climate change to antimicrobial resistance include increased growth rates of bacterial and horizontal transfer of genes, rising antimicrobial resistance prone infections and use of antimicrobials, changing aquatic ecosystems and species, and co-resistance mechanisms through exposure to heavy metals in soil and water.[32,33] Third, global warming can potentially thaw frozen permafrost and release ancient pathogens to which humans are non-immune. Research found several species of bacteria, virus and fungi in permafrost isolates, with some being thousands of years old yet infectious. Risk of these pathogens to humans needs further research, however, the possibility of disease epidemics cannot be ruled out.[34-36]
- **Sexually transmitted infections-** Climate change and related population displacement has been related to an increase in sexually transmitted and other contact transmitted infections. Extreme weather events increased the risk of HIV spread through changing patterns of sexual contact, reduced access to safe sex products, increased gender-based violence and needle sharing for intravenous drug use.[37,38]

CLIMATE VULNERABILITY AND INFECTIOUS DISEASE IN INDIA

India's vast and diverse geography leads to climate change impacting different regions in different ways, creating distinct vulnerability zones.[39] Climate change has significantly increased the intensity and frequency of extreme weather events in India. The country is ranked 6th in the Climate Risk Index (CRI) and continues to be among the top 10 countries most severely impacted by extreme weather events according to the long-term assessment spanning 1993 to 2022.[40] According to national climate vulnerability assessment report released by the Department of Science and Technology, several states such as Assam, Arunachal Pradesh, Mizoram, Chhattisgarh, Bihar, Jharkhand, Odisha and West Bengal are highly vulnerable to climate change and need urgent adaptation measures. In Assam, Bihar and Jharkhand, over 60% of districts are classified as highly vulnerable.[40]

CLIMATE CHANGE RELATED DISEASE OUTBREAKS IN INDIA

- Kerala has a history of leptospirosis outbreaks, especially during and after the monsoon season. The widespread flooding contaminated water sources and forced people to wade through stagnant water, increasing their exposure to the bacteria. In 2018 Kerala floods, there was increase in leptospirosis cases and deaths occurred after the floods in August. In July 2025, Kerala again saw a sharp rise in cases, with health officials reporting nearly 1,500 confirmed cases and 88 deaths by late July.[41] Studies confirmed a direct temporal and geographical link between the floods affected areas and the concentration of cases.[42]
- Altered precipitation patterns, including both severe flooding and drought, have led to outbreaks of waterborne diseases like cholera and diarrhoea in states such as Odisha. Flooding often contaminates

drinking water sources with waste and sewage, resulting in surges in waterborne diseases. In June 2025, Odisha experienced a major outbreak of cholera and diarrhoea, with over 2500 reported cases and 24 deaths.[43]

- Uttarakhand, a climate vulnerable region of India with over 18000 disasters reported over the past nine years, reports high incidence of vector borne, gastrointestinal and respiratory illnesses. Following the Himalayan Tsunami of 2013, there was a reported outbreak of Hepatitis A in a flood rescue camp among children due to faecal contamination of the water source, highlighting the susceptibility to gastrointestinal infections in post-disaster periods.[44] An outbreak of scrub typhus was also reported following the same disaster event.[45]
- Tamil Nadu reported an acute diarrhoeal disease outbreak linked to damaged subterranean pipelines after cyclone and floods which impacted several south Indian states in 2021.[46]
- The health consequences extend beyond direct heat-related illnesses and have a link to the spread of infectious diseases since mosquitoes depend on surrounding temperatures for their growth, movement, and ability to spread disease, hence changes in climate can influence mosquito-borne viruses.[47,48] Recent assessments show that 76% of India's population spanning over half the districts are at very high heatrisk.[49] When temperatures shift, mosquito life cycles and behaviour shift too, in cities like Delhi and Pune, longer mosquito breeding seasons have led to earlier and more severe dengue outbreaks. Warmer temperatures and increased humidity, especially in the post-monsoon months, provide ideal conditions for mosquito growth and the spread of the virus.[50,51]
- With increasingly severe monsoons and unpredictable rainfall patterns, the risk of disease outbreaks has multiplied. In 2025, the number of disease outbreaks in Maharashtra rose from eight in the first quarter of the year to 27 by August.[52]

NATIONAL PROGRAMME ON CLIMATE CHANGE & HUMAN HEALTH (NPCCHH)

The National Programme on Climate Change & Human Health was launched by the Ministry of Health and Family Welfare (MOHFW), Government of India in 2019. The programme aims to reduce climate change impact on human health through a holistic approach involving awareness generation among key stakeholders, capacity building for health preparedness and response, strengthening of health systems to manage climate-sensitive illnesses, developing partnerships to embed health in the national climate change agenda and promoting research and development in this area. The programme is led by MOHFW and National Centre for Disease Control along with prominent national level institutions or Centres of Excellence such as National Institute of Disaster Management. Several spearheading activities for the prevention of heat, flood and air pollution related illnesses have been undertaken since the inception of the programme.[53-55]

WAY FORWARD: PREVENTION AND MITIGATION

In line with the agenda of the National Programme, addressing climate change induced infectious disease calls for multipronged and interdisciplinary action to safeguard human and animal health, strengthen disaster resilience and advance climate action. The complex interplay of environment, human health and animal health in the pathogenesis of this problem requires a One Health approach to balance the health of human and animal populations and ecosystems.

Human health

Expanding disease surveillance systems beyond tracking human diseases and zoonotic hosts to include environmental and weather data can improve capacity for forecasting disease outbreaks and improve preparedness for action during climate emergencies. Climate-informed disease surveillance systems involve integration of disease surveillance and weather surveillance systems, including early warning and response systems (EWARS) to improve timeliness and impact of disease control. These early warning systems are designed to continuously monitor environmental conditions, forecast high-risk climate events, initiate active disease surveillance, send timely alerts to relevant authorities and establish a mechanism for early response.[56]

Parallelly, enhancing health systems resilience to climate change is of utmost priority. Designing climate-resilient health systems includes upgrading facilities to cater to the increased need of infectious disease care, ensuring continuity of logistics supply chain for essential medicines, diagnostics and vaccines, capacity building of health workforce for disaster response and to identify and treat illnesses associated with climate change, ensuring continuity of care during extreme weather events and adequacy of finances for climate and health emergencies.[57]

Preventive and promotive strategies include awareness generation and risk communication activities for personal preparedness during climate induced health emergency situations, expanding immunization coverage for climate-sensitive vaccine preventable diseases in high-risk areas and infrastructure planning to minimize climate driven displacement and migration.[58,59]

Animal health

Animal disease surveillance and veterinary surveillance systems for major zoonotic diseases and antimicrobial resistance can be expanded and leveraged as part of one health approach to combat infectious disease outbreaks due to climate events.[60] There is an urgent need for cross sectoral AMR surveillance for pathogens which circulate across human, animal and environmental reservoirs, supplemented by strong information management systems to detect and manage the growing threat of antimicrobial resistance.[61]

Climate change and extreme weather events often result in habitat loss and force wildlife closer to human settlements and livestock, thereby increasing human-animal interaction and the risk for zoonotic disease transmission. Conservation of wildlife habitats and ecosystems including forests and wetlands, avoidance of agriculture and livestock grazing close to forest areas, regulation of wildlife trade and overall wildlife ecosystem management can minimize high-risk wildlife and human interactions and prevent disease spill overs.[62]

Environmental health

Climate hazards can directly disrupt and damage sanitation systems thereby promoting communicable disease outbreaks. Climate-resilient water, sanitation and hygiene services systems, designed to anticipate, respond and adapt to climate hazards, can provide communities with continued access to safe water and sanitation in the face of climate emergencies and protect them from disease.[63,64]. This also contributes to vector habitat management by reducing breeding hotspots.

Resettlement of populations at-risk of climate induced disasters can reduce morbidity, mortality and susceptibility to disease.[65] Planning of climate-resilient urban land use and infrastructure can mitigate climate risks, improve disaster preparedness and protect communities against climate hazard impact.[66] Finally, broader climate change mitigation efforts through emission reduction such as transition to renewable energy and adoption of sustainable agriculture and waste management practices can help achieve the Sustainable Development Goals for human health and climate action.[67]

CONCLUSION

Climate change impacts human health and increases the risk of communicable disease directly and indirectly through several pathways, and these risks are expected to grow in future. There is an urgent need to address this problem through multipronged and interdisciplinary action to safeguard human and animal health. This can be achieved through a one health approach involving strengthening health systems resilience to cater to climate induced disease burden, managing human-animal interactions in the face of climate change and extreme weather, environmental engineering for maintaining hygiene and sanitation during and after climate disasters, reducing greenhouse gas emissions through climate actions and building community and ecosystems resilience against climate change.

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