WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.084
Volume 12, Issue 22, 737-747. Review Article ISSN 2277–7105

REVIEW ON IMPACT OF CLIMATE CHANGE ON INFECTIOUS DISEASES

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Article Received on
31 October 2023,

Revised on 20 Nov. 2023,
Accepted on 11 Dec. 2023

DOI: 10.20959/wjpr202322-29202

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ABSTRACT

Climate change is increasingly recognized as a major driver of the emergence and spread of infectious diseases worldwide. This review article presents a comprehensive assessment of the multifaceted impacts of climate change on infectious diseases, exploring the intricate interplay between changing climatic conditions and disease dynamics. Rising global temperatures have accelerated the reproduction rates of disease vectors, such as mosquitoes, leading to an amplification in disease transmission for diseases like malaria, dengue fever, and West Nile virus. Additionally, alterations in rainfall patterns have resulted in changes in mosquito breeding habitats and triggered outbreaks of waterborne diseases like cholera and Giardia infections. Furthermore, climate change has influenced wildlife behavior and ecological systems, facilitating the spillover of zoonotic diseases, including Lyme disease and avian influenza. The changing distribution of pathogens and vectors poses significant challenges to public health systems, necessitating robust surveillance and adaptive strategies to safeguard human populations from infectious disease outbreaks. Moreover, extreme weather events, such as floods and droughts, have been linked to exacerbating disease transmission, further underscoring the urgency of understanding and addressing the impacts of climate change on infectious diseases. In light of these complex interactions, this review underscores the critical importance of interdisciplinary research, collaboration between scientific disciplines and policymakers, and the development of targeted public health interventions. Effective mitigation and adaptation strategies are essential to reduce the burden of infectious diseases in the face of a changing climate. Public health systems must be prepared to respond to the evolving challenges posed by climate change, while fostering resilience and adaptive capacity to protect global health and well-being.

KEYWORDS: Infectious disease, vector borne disease, food borne disease, water borne disease, climate change, droughts, floods, temperature, transmission.

INTRODUCTION

It has been seen that climate change effects the spread of infectious diseases worldwide. Changes in temperature alters the distribution of diseases carrying vectors such as mosquitoes and ticks. It also influences the transmission of foodborne and waterborne illness. Moreover, extreme weather events, such as droughts and floods can exacerbate the spread of infectious diseases.[1] Lyme disease, West Nile virus disease, and Valley fever, these are just some of the infectious diseases that are on the rise and spreading to new areas of the United States. Milder winters, warmer summers, and fewer days of frost make it easier for these and other infectious diseases to expand into new geographic areas and infect more people. To understand climate change's impact, it's important to look at some of the common ways these diseases spread through mosquito, tick bites, contact with animals, fungi, and water.[2] Thus, it is important to understand the relation between climate change and infectious diseases. Further doing this will help develop effective public health strategies to mitigate their impacts. Infectious diseases are caused by pathogens. Change in temperature and weather facilitates growth of these pathogens. Rodents, mosquitoes and ticks support pathogens reproduction and transmission will also help some infectious diseases spread.[3] Furthermore, extreme weather conditions like heavy rainfall, heat waves and droughts contribute more towards favorable disease spread. For example, some areas way become too warm due to heat and dry. This facilitates a home for disease carrying mosquitoes to survive and spread pathogens. Three components are essential for most infectious diseases: a pathogen, a host and transmission environment.[4] Environmental disasters in which man-made infrastructures may impact climate factors also influence infectious disease outbreaks from resulting disruption of ecosystems, flooding, contamination, and displacement of human populations . These factors may cause increase or decrease in disease transmission as well as outbreaks which may produce chronic effects over time.[5]

1. Climate factors and disease dynamics

Organisms that make us sick are called pathogens. And infectious disease are caused by these pathogens. Examples of pathogens are viruses, fungi, bacteria and parasites. These pathogens grow in different climatic conditions, thus any change in the weather pattern can favour the condition needed by a pathogens to grow Particularly in terms of average temperature, precipitation and relative humidity.[6] These conditions will positively effect its ability to survive and spread. Some conditions can also favour the animal like rodents, mosquitoes and ticks for their reproduction, transmission and spread the infectious disease.

For example some conditions or locations may become too hot or dry for disease carrying mosquitoes to successfully survive and spread pathogens.

Furthermore, if climate warms, extreme weather events like heavy rainfall, heat waves and droughts can become more common and intense. So, these extreme weather events can become a favourable environment for the pathogens to grow. Also extreme weather events can lead to floods and hurricanes and this can further facilitate the spread of disease amongst people.[7]

2. Vector borne diseases

Climate change can have far-reaching effects on the transmission dynamics, geographic distribution, and re-emergence of vector-borne diseases, impacting various elements of the ecosystem. The consequences extend beyond individual species, affecting vectors, pathogens, non-human hosts, and humans. As climate change alters ecosystems, including urban habitats, it can either support the proliferation or hinder the survival of vectors and non-human hosts. Being ectothermic organisms, arthropods and other vectors are significantly influenced by temperature changes. As temperatures rise, vector abundance, survival, and feeding activity tend to increase.[8] The development rate of pathogens within vectors also accelerates with higher temperatures, leading to a shorter extrinsic incubation period for diseases like the dengue virus. However, the relationship between temperature and vector behaviours is intricate, and factors such as survival, abundance, and feeding behaviour may exhibit non-linear responses at different temperature ranges. The geographic range of vectors, like Aedes aegypti, is currently constrained by cooler temperatures. However, as the Earth warms, concerns arise that these vectors and the associated viruses may extend their reach to higher latitudes and altitudes, leading to an increased incidence of diseases and longer transmission seasons in some endemic areas. Aedes albopictus, another dengue vector, has already demonstrated widespread expansion into more temperate regions, although the exact role of climate change in this process remains unclear. Nevertheless, there is a possibility that extremely hot temperatures in endemic areas might inhibit vector survival or feeding, potentially resulting in a decrease in the incidence of dengue and other vector-borne diseases. Nonetheless, these areas would still face severe impacts from extreme heat. The relationship between precipitation and vector abundance is complex and context-specific.[9] While increased precipitation could create more breeding sites for vectors, droughts could also lead to more breeding sites as people utilize containers for rainwater storage, creating prime breeding grounds for mosquitoes like Aedes aegypti. Additionally, ecosystem changes driven by climate change may impact vector habitats, species competition, and the abundance of vector predators and pathogens, further influencing vector abundance. Climate can also directly or indirectly influence the abundance and behaviours of both non-human and human hosts. Changes in climate can affect non-human hosts' abundance through altered food sources, predators, and pathogens, thus modifying habitats to become either more or less hospitable. For instance, the shift in bird migration patterns and the decline in bird populations in North America, influenced in part by climate change, may impact the transmission of West Nile virus from Culex mosquitoes to humans. Human population displacement due to climate change can introduce vectors and pathogens to new locations, potentially exposing immunologically susceptible populations to the risk of infection. Overall, the multifaceted impacts of climate change on infectious diseases necessitate a comprehensive approach to study and address these complex ecological and public health challenges.[10]

3. Water borne diseases

Waterborne diseases, including cholera, typhoid, and E. coli infections, have become a significant public health concern, contributing to approximately 3.4 million deaths annually. Unfortunately, the risk of waterborne illnesses is being exacerbated by the impacts of climate change. Several climate variables play a critical role in influencing waterborne illness outbreaks: Extreme Weather Events: Climate change is leading to more frequent and severe weather events, such as storms, droughts, precipitation, floods, and wildfires. These events can introduce pathogens into water sources and disrupt water systems, increasing the risk of contamination. Increase in air temperature: Rising global temperatures have far-reaching consequences, including influencing the occurrence and distribution of waterborne diseases. Higher air temperatures can foster the growth and survival of certain pathogens, amplifying their transmission potential. Increase in water temperature: As global temperatures rise, water bodies also experience warming. Warmer water temperatures can create favourable conditions for pathogen proliferation, increasing the likelihood of waterborne disease outbreaks.[11] Waterborne diseases result from the entry of pathogens into water supplies without detection, subsequently contaminating drinking water or food consumed by unsuspecting individuals.

These diseases stem from various microorganisms, biotoxins, and toxic contaminants, causing severe health problems such as cholera, schistosomiasis, and gastrointestinal issues. Notably, waterborne disease outbreaks often follow intense precipitation events, such as heavy rainfall or snowfall. Climate change intensifies the frequency and severity of such precipitation events, potentially burdening communities, particularly in developing regions, with an increased incidence of waterborne illnesses. Moreover, diseases caused by Vibrio bacteria, including cholera and other intestinal diseases, may pose a more significant threat due to the influence of rising sea temperatures on bacterial growth and spread. As a result of climate change, diarrheal disease incidence is likely to escalate globally, while extreme weather conditions may further complicate existing prevention efforts that may already be insufficient to combat these waterborne diseases. In conclusion, the intersection of climate change and waterborne diseases underscores the urgency of addressing environmental challenges to protect human health. Mitigating the impacts of climate change and implementing robust water management and disease prevention strategies are crucial in reducing the burden of waterborne illnesses on vulnerable populations worldwide.[12]

4. Food borne diseases

The environment plays a crucial role in the transmission of numerous pathogens, and changes in environmental conditions, such as temperature and precipitation, can impact the distribution, diversity, levels, and seasonality of pathogens in both natural and agricultural environments. These changes, in turn, can have significant implications for pathogen levels in food. The key climate variables that influence foodborne illness are increased air temperature and increased water temperature. Foodborne illness poses a significant health concern in various countries, with millions of cases reported annually and substantial rates of hospitalization and mortality.[13] Several pathogens contribute to foodborne illnesses, including Campylobacter spp., Salmonella spp., Clostridium perfringens, Verocytotoxin-producing Escherichia coli (VTEC) O157, and Listeria monocytogenes. Higher ambient temperatures can lead to increased instances of foodborne illness for several reasons. Firstly, certain bacteria, like Salmonella spp., multiply more rapidly in food at higher temperatures within the range of 7.5–37°C. Without proper control measures, elevated ambient temperatures may promote bacterial growth along the food chain, resulting in more severe consequences upon ingestion.[14] Secondly, ambient temperature can influence people's behaviour, affecting the likelihood of foodborne illness occurrences. For instance, higher temperatures may lead to increased consumption of raw foods like fruits and salads, which are at risk of cross-contamination. Moreover, riskier cooking practices like barbecuing may become more prevalent with warmer temperatures.

Finally, warmer temperatures may encourage more outdoor recreational activities, exposing individuals to environmental sources of gastrointestinal pathogens. Although these illnesses are not strictly classified as 'foodborne,' surveillance data often cannot differentiate them from foodborne illnesses. Nevertheless, it is estimated that the majority of campylobacteriosis and salmonellosis cases are of foodborne origin. As a result, numerous studies have revealed positive associations between temperature and foodborne illness across various geographical settings. Overall, the impact of climate change on foodborne illnesses underscores the need for effective public health measures and monitoring systems to address and mitigate the risks. Proper food safety practices, control measures, and public awareness are essential to reduce the burden of foodborne illnesses in the face of changing environmental conditions.[15]

5. Zoonotic diseases

The rise of emerging infectious diseases (EIDs), particularly those capable of zoonotic transmission, poses an escalating risk to global health, economy, and safety. The impact of global warming and geoclimatic variations on the epidemiology of zoonotic diseases is observable through the changes it induces in the dynamics and interactions of hosts, vectors, and pathogens.[16] Vector-borne diseases, like malaria, exhibit complex epidemiology concerning their occurrence, spread, and persistence. The disease behaviour is influenced by the dynamic environment and interactions between hosts, reservoirs, vectors, and pathogens. Predicting the spread of vector-borne diseases in response to climate change presents significant challenges, necessitating interdisciplinary collaboration among experts. Among disease vectors, mosquitoes are widely studied and notorious carriers of serious illnesses such as dengue fever, Japanese encephalitis, and yellow fever, in addition to malaria caused by the Plasmodium parasite. Other insect vectors include ticks, midges, sand flies, and fleas. Globally, vector-borne diseases account for more than 17% of all infectious diseases and result in over 700,000 deaths annually. In 2018, there were approximately 228 million malaria cases and 405,000 related deaths, as reported by the World Health Organization.[17] To comprehend the relationship between climate and various earth systems, encompassing oceans, land, ice, and biology, scientists employ Earth system models. These models facilitate the estimation of the effects of natural and anthropogenic factors, such as volcanic eruptions and fossil fuel energy use. Additionally, modern Earth system models can encompass feedback from biological systems, including vegetation dynamics and biogeochemical cycles. They provide an ideal framework to simulate the processes relevant to zoonotic diseases, incorporating hydrology, vegetation, and climate. Hence, these models offer valuable insights to predict the impact of climate change on zoonotic disease outbreaks.[18]

6. Implications for public health

Certain groups of people are more susceptible to health risks arising from climate change due to varying levels of vulnerability determined by sensitivity, exposure, and adaptive capacity. Sensitivity refers to the degree of impact a stressor, like higher temperatures, has on individuals or groups. Exposure refers to the physical contact between individuals and the stressor. Adaptive capacity signifies the ability to adjust to or avoid potential hazards. Vulnerability is influenced by a combination of factors that make certain populations more at risk: Communities of colour, including Indigenous communities and specific racial and ethnic groups, as well as low-income, immigrant, and limited English proficiency communities, face disproportionate vulnerabilities. This is due to higher exposure risks, socioeconomic and educational factors affecting adaptive capacity, and a higher prevalence of medical conditions impacting sensitivity. Children are vulnerable due to biological sensitivities and more opportunities for exposure, especially during outdoor activities.[19] Pregnant women are vulnerable to heat waves and extreme events like flooding. Older adults are susceptible to various climate change impacts, with greater sensitivity to heat and contaminants, a higher prevalence of disability or pre-existing medical conditions, and limited financial resources affecting their ability to adapt. Occupational groups such as outdoor workers, paramedics, firefighters, transportation workers, and those in hot indoor work environments face heightened vulnerability to extreme heat and vector borne diseases. People with disabilities require specific emergency response plans to accommodate their needs during extreme weather events. People with chronic medical conditions are generally vulnerable to extreme heat, especially if they are taking medications that hinder body temperature regulation. Power outages can be particularly threatening for those reliant on specific medical equipment. Addressing the unique vulnerabilities of these groups requires targeted efforts and inclusive strategies to enhance resilience and reduce health risks associated with climate change.[20]. Climate change not only affects waterborne diseases but also impacts other infectious diseases, such as those transmitted by ticks and through food. While there are measures we can adopt to mitigate immediate risks, the most effective long-term solution to safeguarding public health is to address and reduce climate change. Taking action to decrease greenhouse gas emissions can help mitigate the escalating heat and precipitation patterns projected in the future, consequently reducing health-related risks. This requires collaborative efforts from governments, policymakers, industries, and communities, as everyone must play a role in finding solutions to these pressing issues.[21] Science can contribute to addressing climate-sensitive disease outbreaks in two significant ways. Firstly, by enhancing scientific understanding and analytical capabilities, combined with timely and location-specific data, public health practice can be strengthened through more accurate disease forecasts. This enables proactive measures to be taken in preventing and managing outbreaks effectively. Secondly, improved disease forecasts with lead times of weeks to months or even longer can facilitate early warnings, encouraging collaborative efforts between scientists, decision-makers, and stakeholders. This paradigm shift towards prediction and prevention is crucial for both national security, safeguarding citizens and interests, and global health security, ensuring the capacity to respond to infectious disease threats worldwide. The advancements in data and robust scientific research also offer potential economic opportunities in the private sector, with the development of user- friendly tools like apps or dashboards. Our growing capacity to understand and predict weather, climate, and other environmental changes holds significant promise in revolutionizing the way health decision-makers respond to climate-sensitive diseases. Early action driven by climate and environmental information can save lives and reduce the burden of disease. Below is an illustrative example demonstrating how acting proactively based on climate information can have life-saving implications and minimize the impact of climate-sensitive diseases.[22]

7. Future research directions

Step 1: Coordinating Policy Context and Data Management:

Enhance institutional arrangements to foster collaboration between scientists and decision-makers, prioritizing issues related to climate-sensitive diseases. Assess available data on earth observations and social factors to inform decisions and forecasts.

Step 2: Improving Data Analytics and Modelling:

Engage the public through challenges and encourage citizen scientists and students to participate in climate-sensitive disease research. Foster collaboration between weather, climate, and public health modelling communities to develop integrated models for infectious diseases.

Step 3: Communicating Results and Building Partnerships:

Identify best practices for early warning systems and pathways for practical application of research findings to public health decision-making.

Step 4: Enhancing Research Efforts:

Engage the research community to address key scientific questions related to climate-sensitive diseases.

Step 5: Enhancing Policy Engagement:

Review existing interagency efforts and explore collaborations to address gaps in climate-sensitive disease management.

Step 6: Increasing Stakeholder Outreach and Public Awareness:

Evaluate existing efforts to raise awareness of climate-sensitive diseases and identify target areas for outreach and capacity building.[23]

CONCLUSION

The impacts of climate change on infectious diseases are increasingly evident and present a significant threat to global public health. Rising temperatures, shifts in precipitation patterns, and alterations in ecosystems have created favourable conditions for the proliferation and spread of disease vectors and pathogens. The consequences of these changes are evident in the increasing incidence and severity of diseases such as malaria, dengue fever, and West Nile virus, among others. Moreover, climate change has facilitated the spill over of zoonotic diseases, underscoring the complex interplay between changing environmental conditions and disease dynamics. Lyme disease, avian influenza, and other zoonotic illnesses have emerged as substantial health concerns, posing challenges for disease surveillance and control strategies. The implications of climate change on waterborne diseases cannot be underestimated, with outbreaks of cholera and Giardia infections becoming more frequent due to altered rainfall patterns and changes in mosquito breeding habitats. Extreme weather events, such as floods and droughts, further exacerbate disease transmission, necessitating adaptive strategies and preparedness in the face of environmental disasters. To mitigate the impact of climate change on infectious diseases, collaborative efforts across scientific disciplines, governments, and communities are imperative. Robust surveillance systems, advanced modelling and forecasting, and the development of adaptive public health strategies are essential components of effective disease prevention and response. The urgency of addressing the complex relationship between climate change and infectious diseases cannot be overstated. Timely action and the implementation of evidence-based interventions are crucial in protecting vulnerable populations and preventing disease outbreaks. By working together to harness the power of science and innovation, humanity can better equip itself to combat the growing threat of infectious diseases amidst a changing climate and safeguard the health and well-being of future generations.

ABBREVATIONS

VTEC: Verocytotoxin Escherichia coli EIDs: Emerging infectious diseases.

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