



## The Epidemiological Impact of Climate Change on Vector-Borne Diseases: Review

**1<sup>-</sup> Amro Ahmed Nasser Khamjan,<sup>2-</sup> Abdulaziz Mohammed Ali Ghazwi,<sup>3-</sup> Abdu Ahmed Nasser Khamjan,<sup>4-</sup> Tawfig Yusef Khamees Yusef,<sup>5-</sup> Wael Zaylaee Ahmed Shahhar,<sup>6-</sup> Ahmed Mohammed Abdullah Madkhali,<sup>7-</sup> Ali Khamis Ahmed Burayk,<sup>8-</sup> Mohammad Ali Ahmad Damri,<sup>9-</sup> Ahmad Salem Ali Alfaifi,<sup>10-</sup> Abu Bakr Mohammed Qaba Ahmed,<sup>11-</sup> Amjad Hmad Ahmad Hadi,<sup>12-</sup> Adnan Mohmmad Hasan Maken,<sup>13</sup> Health Cluster,**

1. Ksa, Ministry of Health, Vector borne control at Jazan Public Health Department
2. Ksa, Ministry of Health, Enviromental health at jazan public health department
  3. Ksa, Ministry of Health, Jazan Health Cluster
  4. Ksa, Ministry of Health, Jazan Health Cluster
  5. Ksa, Ministry of Health, Jazan health cluster
  6. Ksa, Ministry of Health, phcc-aboarish-Center
  7. Ksa, Ministry of Health, Jazan Health Cluster
  8. Ksa, Ministry of Health, Jazan Health cluster
  9. Ksa, Ministry of Health, Jazan Health Cluster
10. Ksa, Ministry of Health, Vector borne control at Jazan Public Health Department
  11. Ksa, Ministry of Health, phcc-aboarish-center
  12. Ksa, Ministry of Health, Jazan health cluster
  13. Ksa, Ministry of Health, Easa saiban mawikli

### Abstract

**Background:** Climate change significantly impacts vector-borne diseases (VBDs), posing challenges for public health and nursing practice. As temperatures rise and weather patterns become increasingly erratic, the distribution of vectors such as mosquitoes and ticks expands, heightening the risk of diseases like malaria and dengue. This review synthesizes findings from ten studies that examine how climatic variations influence VBD transmission dynamics and their implications for nursing and healthcare interventions.

**Methods:** A comprehensive literature search was conducted, focusing on peer-reviewed articles that explore the relationship between climate change and VBDs. Key metrics included changes in vector distribution, incidence rates of VBDs, and the effectiveness of public health responses. The results indicate a clear correlation between climatic factors—such as temperature and precipitation—and the proliferation of VBDs. Specifically, the studies reveal a nonlinear relationship where optimal climatic conditions facilitate vector survival, while extreme weather events exacerbate disease outbreaks.

**Results:** As climate change continues to evolve, nursing education must adapt to include strategies for addressing the emerging challenges posed by VBDs. This review underscores the need for an integrated approach that combines nursing expertise with public health strategies to mitigate the impact of climate change on vector-borne diseases.

**Conclusion:** The findings highlight the urgency for healthcare systems to enhance preparedness and response strategies for VBDs influenced by climate change. Collaborative efforts among healthcare professionals, policymakers, and researchers are essential to safeguard public health in a warming world.

**Keywords:** Climate change, vector-borne diseases, public health, epidemiology.

## 1. Introduction

Climate change, impacting the globe during the previous century, has resulted in a general increase in temperatures from 1906 to 2005 [1]. The Sixth Assessment Report (AR 6) of the Intergovernmental Panel on Climate Change (IPCC) indicates that the global average surface temperature may attain or surpass 1.5 °C during the next twenty years, with heightened precipitation, glacial melting, and elevated sea levels [2-4]. The intensification of climate change will result in frequent severe weather events, posing significant risks to human life and health. Currently, around 30% of the world population endures harsh weather conditions that surpass human thermoregulatory limits for a minimum of 20 days annually. Furthermore, global warming and excessive precipitation might facilitate the proliferation and spread of illnesses, resulting in a minimum of 150,000 fatalities annually globally [5].

This Special Issue has 10 studies that elucidate the effects of climate change on ecosystems and human health from many disciplinary viewpoints, including phytology, biology, epidemiology, pathology, and molecular biology. In phytology and biology, climate change has been shown to influence the regional distributions of flora and fauna [6-8]. The prospective global proliferation of vector species responsible for vector-borne diseases (VBDs) has been assessed in epidemiology and pathology, demonstrating the invasive and evolutionary adaptability of these vectors to various ecological and environmental settings. The influence of non-climatic variables on vector-borne diseases has also been evaluated [10-14]. Based on these 10 publications, we provide an additional discourse on climate change and vector-borne diseases (VBDs).

Vector-borne diseases (VBDs), being climate-sensitive, are evaluated globally to illuminate potential future trends, especially in view of the heightened probability of climate change [15]. The influence of climate change on vector-borne diseases (VBDs) is an undeniable reality, presenting significant problems for public health. VBDs encompass rodent-borne diseases (plague, hemorrhagic fever, hemorrhagic fever with renal syndrome, leptospirosis, cutaneous leishmaniasis, and Puumala hantavirus), mosquito-borne diseases (malaria, dengue, Zika, chikungunya, West Nile virus, Ross River virus, and Japanese encephalitis), tick-borne diseases (tick-borne encephalitis, Lyme disease, etc.), and other arthropod-borne diseases [16,17]. Annually, over 700,000 individuals succumb to vector-borne diseases (VBDs), with over 80% of the worldwide populace residing in high-risk regions susceptible to one or more forms of VBDs [18]. Among the 250 nations globally, 86% (218 countries) are conducive to the survival and reproduction of arboviral diseases [19].

The impact of climatic conditions on the transmission and proliferation of vector-borne diseases may be examined at the local, regional, and severe climate levels [20-22]. The local climate, characterized by temperature, precipitation, and wind, primarily influences the transmission of vector-borne diseases (VBDs) by impacting their vectors; conversely, regional climate, indicated by phenomena such as the El Niño–Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), and Indian Ocean Dipole (IOD), predominantly exerts indirect effects on VBDs by altering local climate [23,24]. Simultaneously, severe climatic occurrences, including heat waves, cold waves, floods, and droughts, increase the likelihood of vector-borne disease spillover [25,26]. We also examine the interplay between non-climatic variables (such as land use and human movement) and climatic parameters concerning the transmission and dissemination of vector-borne diseases (VBD) [27-29]. Furthermore, we examine the influence of coronavirus disease 2019 (COVID-19) on climate change and its consequences on the outbreak risk and incidence of vector-borne diseases (VBDs) [30]. Our research seeks to thoroughly evaluate the effects of climate change on the transmission and proliferation of vector-borne diseases (VBDs) to facilitate targeted prevention, control, and comprehensive intervention strategies for VBDs.

## 2. Non-Linear Impacts of Local Climate on Vector-Borne Disease Transmission

The influence of local climatic variables (namely temperature, precipitation, and wind) on vector-borne disease transmission is mostly nonlinear. These parameters may influence the distribution range, population dynamics, and viral transmission capacity of vectors, hence affecting the developmental response of diseases [29,31]. The climatic adaptability of VBD transmission will be significantly elevated under appropriate temperature circumstances. When temperatures fail to meet optimal circumstances, the risk of vector-borne disease (VBD) transmission escalates with rising temperatures; conversely, when temperatures above the optimal peak, the risk of VBD transmission diminishes as temperatures continue to rise. In inappropriate temperature circumstances, vector survival may diminish, thereby impairing the transmission potential of vector-borne diseases (VBDs), which also directly influences the progression of vector-dependent illnesses [32-34]. The lifespan and reproductive range of rats typically spans from 10.0 to 30.0 °C, but the optimal temperature range for the transmission of rodent-borne diseases is between 20.0 and 30.0 °C [35]. The anticipated epidemic proliferation of plague outbreaks is favorable between 11.7 °C and 21.5 °C, peaking at around 17.3 °C [36]. Temperature influences the development and survival of mosquitoes, with an optimal thermal range that is diminished by extreme heat or cold. Diseases such as malaria, dengue, and Zika exhibit significant nonlinear responses to temperature and climate change in ectothermic vectors and parasites. The temperature range for the transmission of mosquito-borne illnesses is typically 9.0–38.0 °C, with the optimal range being 23.0–29.0 °C [37].

Numerous investigations have shown that precipitation has a nonlinear influence on VBD transmission. An appropriate amount of precipitation may facilitate the development of vector breeding habitats, particularly in arid regions, which might provide abundant food resources for rodents [38-40]. Precipitation often enhances mosquito oviposition and reproduction, although the correlation between rainfall and malaria incidence first rises and then declines with increased precipitation, peaking at 120 mm. Concerning ticks, an excess of 28 days of precipitation results in a major rise in their population; yet, substantial and prolonged rainfall may eliminate ticks, their eggs, and larvae, hence diminishing their numbers [41,42].

Elevated wind velocities impede mosquito flying, reduce their population density, and diminish their propensity to alight on and bite hosts [43]. A supporting example of this perspective is the discovery that strong winds hindered the transmission rate of the West Nile virus; in contrast, there is no evident adverse trend regarding the impact of low wind speeds on mosquitoes. [44, 45]. This also indicates a non-linear impact on VBD transmission.

Climate change significantly influences the transmission of vector-borne illnesses, generally expanding their climate-adaptive transmission zones. Climate change in Europe is expected to extend the range of ticks to higher latitudes and elevations, thereby elevating the prevalence of tick-borne illnesses [46]. In South Africa, increasing temperatures may diminish habitat appropriateness for some tick species (Acari: Ixodidae), thereby reducing the prevalence of associated disorders [47]. According to IPCC warming predictions, the environmental conditions for chikungunya transmission will become more favorable in western and central Europe, while remaining largely unsuitable in Southern Europe [48]. Climate change has resulted in a 40% rise in the adaptability of rats in some high-altitude regions [49]. For mosquitoes and ticks, a warmer environment often increases the risk of disease transmission in high-latitude and high-altitude locations, but the risk may normally diminish in tropical places. In rodent-borne illnesses like plague, both rodents and fleas affect pathogen transmission; however, the impact of elevated temperatures on the suppression of fleas (vectors) and flea-mediated transmission of pathogenic bacteria remains unknown [50].

### **3. Temporal Delay in Local and Regional Climate Influences on Vector-Borne Disease Transmission**

Regional climate mostly influences vector-borne diseases (VBDs) via local climatic conditions, which subsequently affect the biological habitat, distribution, and population dynamics of vectors, consequently altering the transmission rate of infections and influencing VBD epidemics. Multiple studies have demonstrated that local climate has a time-lag influence on the spread of vector-borne diseases in the near term. Numerous studies have shown a temporal lag impact of regional climate on rodent-borne illnesses,

including renal hemorrhagic fever, leptospirosis, and cutaneous leishmaniasis [51,52]. The temporal lag ranges from 1 to 6 months, or even up to one year, owing to the intricate biological traits of rodent-borne illnesses; for instance, temperature influences the human plague in Arizona and New Mexico with a 2 to 3-month lag, but precipitation has a 1 to 2-year lag impact. A substantial body of research has examined time-lag effects in mosquito-borne illnesses, including dengue fever, malaria, chikungunya, Ross River virus, and Japanese encephalitis [53-55]. The latency period for these illnesses is often regarded as around 0–2 months, attributable to indirect impacts on the life cycle and population density of mosquitoes [56].

The time-lag effects of regional climate exhibit broader ranges and extended durations compared to local climate impacts, making them more relevant for proactive disease prevention forecasts. ENSO exemplifies the most major instance of quasi-periodic climatic variability on an interannual scale, influencing global weather patterns. The global temperature variability pattern linked to ENSO has been shown to influence several infectious illnesses, including those transmitted by rodents, mosquitoes, and ticks. For instance, the escalation of human plague incidence in China was significantly correlated with ENSO over short (2–3 years), medium (6–7 years), and long durations (11–12 years, 30–40 years) [57]. Dengue incidences in India, influenced by ENSO, had a positive correlation with a 3–6-month time lag from 2010 to 2017, facilitating the prediction of human epidemics in advance. The ENSO index seems to be an inadequate measure of climatic variability in Europe; conversely, the NAO has been shown to influence the incidence of 13 infectious illnesses [22]. Furthermore, multi-decadal temperature variations have been shown to affect the NAO–plague connection, exhibiting a delayed effect of 15–22 years across several European locations [57]. Overall, these regional climates significantly impact the prevalence of vector-borne diseases (VBDs) and human health by affecting precipitation and temperature and may serve as early indicators for disease management and prevention.

#### **4. Effects of Extreme Climate Distribution Expansion on Vector-Borne Disease Proliferation**

As the occurrence of climatic extremes rises due to accelerating climate change, it is crucial to comprehend the effects of climate range boundaries and constraints on vector-borne diseases. Severe climatic conditions have a U-shaped influence on the dissemination of vector-borne diseases (VBDs). Adaptive climatic settings often exhibit the lowest risk of vector-borne disease (VBD) transmission, but severe climates that deviate from adaptive circumstances tend to elevate the risk of VBD spread. Extreme climate events may elevate the danger of disease transmission and the overflow of vector-borne diseases (VBDs), whereas adaptive climatic circumstances correlate with a reduced growth of VBDs (Figure 4B). Severe climatic conditions have been identified as a primary factor in disease epidemics, raising concern throughout the worldwide population. The effect of climate change on vector-borne diseases (VBDs) is more pronounced in the peripheries of various climatic zones, significantly affecting the geographical distribution of vectors [20].

Various forms of severe climatic events (heat waves, cold waves, floods, and droughts) have distinct influences on the geographical proliferation of vector-borne diseases (VBDs). The influence of heat waves on mosquitoes is contingent upon their timing and length; these occurrences often enhance population growth during early embryonic phases, but frequently inhibit the overall life cycle. Therefore, during short-term heat waves, it is recommended to mitigate the proliferation of mosquito-borne vector-borne diseases resulting from the accelerated development of mosquitoes. Conversely, an experimental investigation in Kenya revealed that cold waves during the summer months promote mosquito proliferation due to the persistently high temperatures throughout the year; hence, cold waves in Kenya moderate summer temperatures and facilitate the development of vector-borne diseases [58]. Simultaneously, floods eliminate the aquatic phase of mosquitoes and their eggs from breeding locations, but the stagnant water remaining post-flood creates an ideal environment for mosquitoes. During intermittent droughts in wetlands, mosquito populations surge as their predators and rivals are eradicated [58]. Elevated mosquito numbers would therefore result in a heightened risk of spillover for mosquito-borne infectious illnesses. Climatic trends influence vector-borne diseases (VBDs); for instance, in northern China (arid climate), rodents are anticipated to thrive with increased precipitation, while in southern China (humid climate),

excessive rainfall would obliterate rodent nests, thereby affecting the intensity of human plague due to its positive correlation with rodent density.

Consequently, in the realm of climate change, climatic extremes are anticipated to provide heightened hazards and opportunities for the proliferation of vector-borne diseases (VBDs) [59]. Extreme winter temperatures diminish snow cover, facilitating interactions between bank voles and people, exemplified by the Puumala hantavirus (PUUV) outbreak of 2006–2007 [60]. Research in Ecuador revealed that under severe climatic conditions, *Aedes aegypti* may extend its range in hilly regions by as much as 4,215 km<sup>2</sup>, so placing over 12,000 individuals at risk of illness [37]. In India, the rise in heat wave occurrences has led to a higher prevalence of chikungunya and dengue in coastal districts, while Japanese encephalitis and malaria have become more common in interior districts [61]. Extreme heat, drought, and flooding adversely affect tick distribution, potentially disrupting the habitat of *Ixodes* ticks in Europe, particularly in Northern and Central Europe. Nonetheless, extreme weather is projected to increase the distribution of *Ixodes* ticks in Europe by 3.8% between 2040 and 2060, with tick-borne encephalitis (TBE) anticipated to spread to higher altitudes and latitudes. In New York State, the yearly incidence of Lyme disease escalates by 4–10% with moderate winter temperatures and by 2% with prolonged spring and summer days [62].

## 5. The COVID-19 pandemic

The influence of the COVID-19 pandemic on climate change remains contentious in the near term, but COVID-19 may create new conditions that affect the prevalence of vector-borne disease outbreaks. During the COVID-19 pandemic lockdowns, human activity and air pollution decreased, resulting in a mitigation of climate change. Conversely, a comparable decrease in global SO<sub>2</sub> emissions was seen to diminish the aerosol cooling effect, potentially resulting in warming [63]. Potential climatic alterations may influence the transmission and proliferation of climate-sensitive vector-borne diseases (VBDs).

In addition to climate change, inadequate vector testing and control measures and insufficient financial resources for VBD monitoring during the COVID-19 pandemic have resulted in a heightened incidence of VBDs [64,65]. Routine vector testing and control efforts mandated by the Department of Prevention and Control, including regular home surveys, have been discontinued during the COVID-19 quarantine [66]. Numerous nations have temporarily halted adult monitoring and larval management efforts for *Aedes aegypti*, leading to an elevated risk of dengue transmission. Simultaneously, the economic strain induced by COVID-19 has resulted in inadequate financial support for VBD monitoring. Furthermore, several vector-borne diseases with the same symptoms have been neglected and underdiagnosed during the COVID-19 epidemic, leading to their neglect rather than eradication [30].

Lockdown regulations have significantly decreased imported cases and obstructed avenues of vector-borne disease transmission [67]. Statistics reveal a significant reduction in vector-borne illnesses during the COVID-19 pandemic across several nations [40]. Two significant factors contribute to the reduction in the prevalence of VBDs. One explanation is that entrance and departure controls in several countries have significantly reduced imported cases and obstructed the source of disease transmission [110]. The decline in human outdoor activities and the implementation of physical distancing measures decreased the likelihood of mosquito bites, hence reducing the risk of transmission of mosquito-borne diseases [67,68]. Consequently, measures aimed at preventing and controlling COVID-19 transmission also have a preventative influence on vector-borne diseases (VBDs).

## 6. Conclusions

This document summarizes the various effects of many climatic conditions on the transmission and proliferation of vector-borne diseases in the context of climate change. The local climate has non-linear direct impacts, leading to fast transmission in favorable circumstances and a decrease in unfavorable environments, with local temperature exhibiting a distinct n-shape. The regional climate indirectly influences vector-borne diseases (VBDs) via changing local climate, resulting in an inherent temporal lag in the impact on disease transmission. Severe climatic events may exacerbate disease transmission, resulting in the proliferation of vector-borne disease dispersion. Furthermore, land use and human movement

significantly interact to influence the spread of vector-borne diseases, increasing the likelihood of transmission and spillover. The influence of the COVID-19 pandemic on the relationship between climate change and vector-borne disease transmission remains unresolved.

The quarantine rules used during the COVID-19 pandemic effectively prevented the importation of vector-borne disease (VBD) cases; this excellent preventive and control strategy merits adoption and application in the realm of VBDs. The influence of COVID-19 on climate change remains contentious, and its prospective impact on vector-borne diseases may become more evident over time. Thus, it is essential to further investigate the possible impact of COVID-related climate change on vector-borne diseases (VBDs). Simultaneously, the enhancement of surveillance systems pertaining to the COVID-19 pandemic and the establishment of a surveillance network are equally applicable to vector-borne disease surveillance. As monitoring systems advance, it is essential to use techniques from machine learning and artificial intelligence to manage extensive datasets using intricate algorithms in the future.

Significant study has to be conducted about climate change and vector-borne diseases (VBDs). A significant study avenue is the integration of multidisciplinary aspects to assess the influence of climate change on vector-borne diseases (VBDs), particularly concerning computer science, zoology, entomology, ecology, and epidemiology. By integrating many disciplines, we may enhance our comprehension of the effects of climate change on vector-borne diseases (VBDs) and get a more profound insight into the processes behind their incidence and progression. These results may enhance the knowledge of how climate change influences the risk and dissemination of vector-borne diseases (VBDs), so facilitating improved preventive and control measures and ultimately benefiting human health.

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#### التأثير الوبائي لتغير المناخ على الأمراض المنقولة بالنواقل: مراجعة

##### الملخص

**الخلفية:** يؤثر تغير المناخ بشكل كبير على الأمراض المنقولة بالنواقل (VBDS)، مما يخلق تحديات كبيرة للصحة العامة والممارسات التمريرية. مع ارتفاع درجات الحرارة وزيادة التقلبات في أنماط الطقس، تتوسع مناطق انتشار النواقل مثل البعوض والقراد، مما يزيد من خطر الإصابة بأمراض مثل الملاريا وحمى الضنك. تجمع هذه المراجعة النتائج من عشر دراسات تستكشف كيف تؤثر التغيرات المناخية على ديناميكيات انتقال الأمراض المنقولة بالنواقل وآثارها على التدخلات التمريرية والرعاية الصحية.

**الطرق:** تم إجراء بحث شامل في الأدبيات، مع التركيز على المقالات التي تمت مراجعتها من قبل الزملاء والتي تبحث العلاقة بين تغير المناخ والأمراض المنقولة بالنواقل. تضمنت المقاييس الرئيسية التغيرات في توزيع النواقل، معدلات الإصابة بالأمراض المنقولة بالنواقل، وفعالية الاستجابات الصحية العامة. تشير النتائج إلى وجود ارتباط واضح بين العوامل المناخية - مثل درجات الحرارة وهطول الأمطار - وانتشار الأمراض المنقولة بالنواقل. وتحديداً، أظهرت الدراسات علاقة غير خطية حيث تسهل الظروف المناخية المثلى بقاء النواقل، بينما تؤدي الأحداث الجوية القاسية إلى تقاوم تفشي الأمراض.

**النتائج:** مع استمرار تغير المناخ، يجب أن يتكيف التعليم التمريري ليشمل استراتيجيات لمواجهة التحديات الناشئة التي تفرضها الأمراض المنقولة بالنواقل. تؤكد هذه المراجعة على الحاجة إلى نهج متكامل يجمع بين خبرة التمرير واستراتيجيات الصحة العامة للتخفيف من تأثير تغير المناخ على الأمراض المنقولة بالنواقل.

**الخلاصة:** تؤكد النتائج على ضرورة تعزيز أنظمة الرعاية الصحية للاستعداد ووضع استراتيجيات استجابة فعالة للأمراض المنقولة بالنواقل المتأثرة بتغير المناخ. تعتبر الجهود التعاونية بين العاملين في مجال الرعاية الصحية وصانعي السياسات والباحثين ضرورية لحماية الصحة العامة في عالم يتعرض للارتفاع الحراري.

**الكلمات المفتاحية:** تغير المناخ، الأمراض المنقولة بالنواقل، الصحة العامة، علم الأوبئة.