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# A Review of the Increasing Global Impact of Climate Change on Human Health and Approaches to Medical Preparedness

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At the end of 2023, the World Health Organization (WHO) identified climate change as the greatest threat to human health. Global climate change is due to rising atmospheric concentrations of greenhouse gasses, primarily due to the burning of fossil fuels, mainly by populations in developed and developing countries. In 2022, the world experienced the highest temperatures for over 100,000 years. However, in 2022, global investment in fossil fuels increased by 10% and reached more than USD 1 trillion. The 2023 *Lancet* Commission report concluded that there has been little progress in protecting individuals from the adverse health effects of climate change. It is clear that global action against climate change needs to move more quickly, and the inequalities in the effects of climate change, including the impact on health, are increasing. This article aims to review the ongoing global impact of climate change on human health at individual and population levels, including recent initiatives and medical approaches to prepare for this increasing challenge.

**Keywords:** **Climate Change • Global Warming • Pollution • Health • Review**

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## Introduction

In October 2023, the World Health Organization (WHO) identified climate change as the greatest threat to human health [1]. Global climate change is due to rising atmospheric concentrations of greenhouse gasses, primarily due to the burning of fossil fuels, mainly by populations of developed and developing countries [2]. The results of climate change include more frequent and intense heat waves and hurricane seasons and increased risks from droughts, wildfires, and floods [2,3]. The combination of all these components of climate change has directly affected human health, compromised public health delivery, including water and sanitation, and has increased the global burden of infectious and noncommunicable diseases [4,5]. Only recently has climate change been recognized as an important driver of changes in the spread of communicable diseases and emerging pathogens (Tables 1, 2) [3,6,7]. Global reports have increasingly raised awareness of the increased incidence and spread of vector-borne diseases, including malaria, dengue, Lyme disease, West Nile virus infection, and the recent interspecies spread of the H5N1 avian influenza virus [1,6,8].

In the past decade, the US National Institute of Environmental and Health Sciences (NIEHS) has supported global research on the health threats from climate change [7,9]. The NIEHS

continues to highlight the direct and indirect ways climate change impacts human health (Table 1) [7,9]. In 2016, a report by the US Global Change Research Program (USGCRP) identified seven main health threats associated with climate change and stressed the importance of continued monitoring and research in these key areas (Table 2) [7,10]. Extremes of temperature and heat waves, a rising sea level, changes in rainfall that result in drought and flooding, and increased frequency and intensity of hurricanes result in injury and illness with increased mortality rates [7,10]. The indirect effects of climate change on health can result from environmental changes, including air pollution, which adversely affects respiratory and cardiovascular health and increases mortality rates [10-13]. Population data from the US have shown that raised air temperature and air pollution significantly increase the rates of preterm birth, low birth weight, and stillbirth [13,14].

Temperature and rainfall changes can alter the distribution, survival, and behavior of insects and other species that transmit diseases to humans, resulting in increased vector-borne diseases and changes in geographical spread [10,15]. Increased rainfall, storms, and raised sea temperatures are associated with more water-borne illnesses [16]. Heat can also threaten food safety by contamination by infectious organisms and toxins or by the increased need for chemicals to control crop infestation and diseases in farmed animals [17]. Impaired mental health

**Table 1.** Interventions on the impacts of climate change on the environment and health [7].

Climate changes	Environmental impacts	Impacts on health	Intervention strategies
Global increase in temperature	Extreme heat	Heat-associated illness, including:	Preparedness strategies
Increased rainfall	Reduced water and food quality	<ul style="list-style-type: none"> <li>cardiovascular disease</li> <li>thrombotic events</li> <li>exacerbation of existing comorbidities</li> </ul>	Early warning systems
Rise in sea levels	Flooding, with increased water pollution, water-borne infections, and zoonotic vector-borne disease	<ul style="list-style-type: none"> <li>dehydration</li> <li>'heat stroke'</li> <li>malnutrition</li> <li>lung disease</li> <li>asthma</li> <li>injuries</li> </ul>	Community awareness and support
Extreme weather events	Air and water pollution		Prevention and reduction of diseases and injury
Changes in the growing seasons and land use	Increased exposure to allergens, food shortages, food contamination, and spread of environmental pathogens	Changes in the patterns of infectious disease	Public health education
		Increase in zoonotic and vector-borne disease	Public health improvements and planning
		Increased risk of epidemics, pandemics, mental and neurological disorders	Implementation of community, national, and global control of climate change and pollution
		Increased mortality	

Modified from: *National Institute of Environmental and Health Sciences (NIEHS)* [7].

**Table 2.** The impact of the specific effects of climate change on human health [7].

Factor	Exposure	Driver	Outcomes	Impact
Heat	Increased temperatures	More prolonged, frequent, and severe heat events	Increased heat-associated morbidity and mortality	Rising temperatures will continue to lead to heat-related illness and death
Reduced outdoor air quality	Reduced air quality due to increased levels of ozone, and particulate matter	Increased temperatures and air pollution	Increased morbidity and mortality from acute and chronic cardiovascular and respiratory disease	Increased temperature, reduced precipitation, and wildfires increase ozone levels and particulate matter
Floods	Damage to infrastructure, sanitation, and contamination	Rising sea levels, storms, increased rain, and hurricanes	Drowning and increased water-borne disease	Inland and coastal floods have negative public health and societal impacts
Water-borne disease	Contamination of fish, shellfish, the sea, rivers, and recreational waterways	Increased sea and river surface temperatures and water runoff on land and the coasts	Increased water temperatures and humidity result in increased diseases from water-borne pathogens	Increasing inland and coastal water temperatures increase the risk of water-borne infections
Vector-borne disease	Increased numbers and distribution of mosquitos, ticks, and mites	Changes in seasonal and global weather patterns	Increased reports of diseases from mosquitos, ticks, and mites	Vectors show earlier seasonal activity and are expanding northwards
Food-borne disease	Seasonal and geographical shift in farming, livestock, and exposure to pathogens	Increased temperatures, season length, humidity, and proximity of livestock	Outbreaks of infections from contaminated food, including <i>Salmonella</i> and <i>E. coli</i>	Longer seasons and warmer winters impact the incidence of pathogen contamination
Mental health	Increased exposure to trauma, illness, and economic insecurity	Reduced availability of food and water, forced migration and uncertainty	Increased levels of anxiety and distress due to grief, illness, and social and economic impacts	Climate change and weather-related events and disasters cause or exacerbate mental illness

Modified from: *National Institute of Environmental and Health Sciences (NIEHS)* [7].

and well-being have recently been acknowledged as effects of climate change, associated with the increased risks to physical health and safety [7,10,18]. This article aims to review the ongoing global impact of climate change on human health at individual and population levels, including recent initiatives and medical approaches to prepare for this increasing challenge.

## The Climate Crisis, Global Variations in Climate, and the Effects on Health

In 2015, *The Lancet* Commission on Health and Climate Change was established and has published annual assessments of climate change and health [19]. The latest *Lancet* Commission report from November 2023 has identified the current impacts on human health and has forecasted an unacceptably high and potentially catastrophic danger to human health from ongoing

global warming [19]. The 2023 *Lancet* Commission report concluded that there has been little progress in protecting individuals from the adverse health effects of climate change [19]. In 2022, the world experienced the highest global temperatures for over 100,000 years [19]. However, in 2022, global investment in fossil fuels increased by 10% and reached more than USD 1 trillion [19,20]. It is clear that global action against climate change needs to move more quickly, and the inequalities in the effects of climate change, including the impact on health, are increasing [19,20]. Low-income and middle-income countries now suffer the most significant risks from climate change, even though high-income countries emit the most significant levels of greenhouse gases (approximately 85%) [1,19,20]. Low-income and middle-income countries are least equipped to defend themselves from the effects of increased temperatures, changes in rainfall, and an increase in water-borne and vector-borne diseases [20].

In 2021, *The Lancet* Countdown in Europe initiative was established to monitor the health effects of climate change [21]. This initiative aimed to provide data to social and political European authorities to implement rapid climate mitigation and responses and adaptation to health-related consequences [21]. The latest report from *The Lancet* Countdown in Europe, published in 2024, tracks 42 indicators that highlight the impact of climate change on human health and the delayed climate action of European countries [21]. In 2023, Europe and the rest of the world experienced record-breaking temperatures, but temperatures in Europe are increasing at twice the global average rate [21,22]. It should be noted that in the latest European report, there have been nine additional health indicators, which include leishmaniasis, ticks and tick-borne disease, food security, production and consumption-based emissions, healthcare emissions, clean energy investment, and engagement with the scientific and political media on climate and health [21]. The 2024 *Lancet* Countdown in Europe Report also presents aspects of inequality by highlighting high-risk groups within Europe and the responsibility for the climate crisis from European countries [21].

### Environmental Effects of Climate Change and Potential Interventions

In 2019, before the outbreak of COVID-19 and the increasing reports of zoonotic disease transmission, in the *New England Journal of Medicine*, Haines and Ebi highlighted the imperative to implement action on climate change to protect human health [23]. They described how climate change increasingly affected human health and health systems and warned of the increasing geographic range and burden of climate-sensitive health outcomes expected to affect global public health and healthcare systems [23]. Haines and Ebi also warned that if no additional actions were taken, worldwide morbidity and mortality could be expected from heat-related illnesses, poor air quality, undernutrition due to inadequate food quality and supply, and some vector-borne diseases [23].

The 2023 WHO report, published in October 2023, highlighted that climate change directly contributes to several recent major humanitarian emergencies, including heatwaves, wildfires, tropical storms, floods, and hurricanes, which are increasing in frequency and scale [1]. The WHO estimates that 3.6 billion people live in areas highly susceptible to the effects of climate change [1]. The WHO reported that between 2030 and 2050, the impact of climate change is projected to lead to approximately 250,000 additional annual deaths, mainly from undernutrition, diarrhea, malaria, and other vector-borne diseases, and the effects of heat stress [1]. An estimate of the costs due to the direct damage to health, excluding costs to agriculture, provision of clean water, and sanitation, is estimated to

be between US\$ 2-4 billion annually by 2030 [1]. Although the WHO and other authorities recommend the urgent reduction in emissions of greenhouse gases by improved transport systems, energy use, food production, and reduced air pollution, these changes are likely to be implemented in time to affect the immediate progression of climate change and its effects [1]. Even if changes happened immediately, the trajectory of climate change and its effects that began many decades ago is unlikely to be rapidly reversed (Tables 1, 2) [7]. Countries that have developed to provide buildings, water supplies, sanitation services, health services, communications, and transportation systems have done so based on assumed seasonal climatic conditions. Global news reports increasingly feature accounts of systems failures due to climate change, heat waves, wildfires, infection outbreaks, water pollution, and water shortages [24].

### The Effects of Increased Temperature on Human Health

The human body has limited mechanisms to cope with excessive heat, including evaporation by sweating, conduction, convection, and radiation, which can be impaired in high-humidity conditions [24,25]. Adaptation to heat exposure declines with age, comorbidities, and prescription medications [4,5]. Reports of heat-related emergency hospital admissions continue to rise, especially when there are extreme heat events (EHes) [24,25]. The harmful effects of heat on the human body can be considered a continuum of changes due to dysregulation of thermoregulatory physiological mechanisms, with varied presentation and severity [26]. Duration and intensity of heat exposure and whether or not exertion is involved can determine whether benign conditions, including heat cramps and heat-related edema, occur or whether heat exhaustion and life-threatening hyperthermia or heatstroke develop [26]. Exertional heatstroke can occur in otherwise healthy individuals who work or exercise in high temperatures [26]. Non-exertional heat stroke can occur with minimal physical activity and affects the elderly and those with comorbidities, including dementia, cardiovascular disease, diabetes, hypertension, renal disease, and alcoholism [26]. Heat stroke causes the dysregulation of the nervous system and cardiovascular systems, with cardiac arrest being the most common mechanism of death [26].

It is now estimated that 30% of the global human population lives where temperatures and humidity are extreme enough to result in excess mortality for at least 20 days of the year and that with continued climate change, 50-75% of all people may live with climate change-associated life-threatening conditions within this century [27,28]. Older age, dementia, cardiovascular disease, diabetes mellitus, COPD and asthma, chronic kidney disease (CKD), and pregnancy increase heat-related mortality [12,29]. Recently, treatment with several classes of

medications has been identified as associations with an increased risk of hospitalization on exposure to heat, including beta blockers, diuretics, angiotensin-converting enzyme (ACE) inhibitors, antipsychotics, and selective serotonin reuptake inhibitors (SSRIs) that are still commonly used to treat depression [30]. A recent finding is that extreme heat exposure may cause some medications to lose efficacy, particularly for some intravenous-delivered and inhaled drugs [31].

Disease-specific considerations for the increased risks to people of older age and with dementia, cardiovascular disease, diabetes mellitus, chronic obstructive lung disease (COPD) and asthma, chronic kidney disease (CKD), and pregnancy have recently been identified and have begun to be explained [32]. Increased temperatures are a risk to patients with diabetes due to changes in their ability to adapt to heat, including impaired sweating and vasodilation, especially with poor glycemic control [33]. Patients with insulin-dependent diabetes may require changes in insulin requirements, blood glucose monitoring, and checks for damage to test strips, glucometers, and insulin pumps [33]. Patients with diabetic neuropathy are at an increased risk of burns, particularly to the feet [33].

Heat exposure is associated with the onset of atrial and ventricular arrhythmias [34]. It is also associated with increased morbidity and mortality from myocardial infarction (MI), heart failure, and stroke [34]. Because patients with cardiovascular disease often have comorbid conditions that include diabetes and take medications that may be affected by heat, this group of patients may be at further increased risk during heat exposure [33,34]. In periods of excess heat, patients with renal impairment have been identified as particularly at risk. For example, a recent multinational meta-analysis study showed that a 1°C increase in ambient temperature increased the risk of renal failure by 1.1% (95% CI, 0.9-1.3) and mortality from renal failure, urolithiasis, and urinary tract infection (UTI) by 3.1% (95% CI, 0.5-5.8) [35]. In 2021, Vicedo-Cabrera evaluated mortality data from 732 regions in 43 countries that had experienced increasing annual temperatures between 1991 and 2018 [36]. The findings showed that overall, in all countries, 37.0% (range, 20.5-76.3%) of warm-season deaths were associated with the effects of heat but with geographical variations [36].

## Reduced Air Quality, Wildfires, and Health

Heat increases ground-level ozone formation, which is associated with flares in COPD, asthma, and bronchoconstriction [37]. High temperatures are significantly associated with increased rates of aggressive behavior, suicide, and substance use, with an increased risk of mortality during heat waves [37]. A significant concern is that higher ambient temperatures during pregnancy are significantly associated with low birth weight,

stillbirth, preterm birth, and congenital anomalies in the fetus and neonate [14].

Until recently, there have been few studies on the effects of increasing wildfires on human health, possibly because wildfire smoke has far-reaching impacts. For example, between 2008 and 2012, up to 30% of the US population lived in areas with at least moderate exposure to wildfire smoke [38]. In June 2023, smoke from wildfires in Canada that drifted hundreds of miles to New York City resulted in emergency department visits of 261 per day, from 181.5 per day, for asthma in pediatric and adult patients [39]. Air pollution from wildfire smoke is associated with significantly increased emergency department visits, hospital admissions, and mortality from cardiovascular disease and chronic renal disease [40]. Outdoor pollution may be monitored, and protective masks may be used to reduce health risks, including FFP2 (Europe), N95 (US), KN95 (China), P2 (Australia/New Zealand), PFF2 (Brazil), KF94 (Korea), and DS2 (Japan) masks that should filter a large proportion of solid, but not gaseous, components of wildfire smoke [41]. Climate change also increases the frequency and intensity of storms and hurricanes, with a peak intensity occurring closer to shore in more northern coastal areas [42]. Climate change also increases the frequency of heavy precipitation events and associated flooding, especially in developing communities [42].

## Climate Change and Vector-Borne Diseases

Climate change is associated with extreme temperatures and increased rainfall precipitation patterns, affecting seasonality, geographic distribution, and the incidence of vector-borne disease [7,43]. In 2020, the WHO reported that vector-borne diseases accounted for more than 17% of all infectious diseases, resulting in more than 700,000 annual deaths worldwide [43]. Vector-borne diseases can be caused by parasites, bacteria, or viruses [43]. Malaria, transmitted by *Anopheles* mosquitoes, resulted in more than 400,000 deaths annually, with most of the deaths occurring in children under the age of 5 years [43]. Also, dengue is the most common viral infection transmitted by the *Aedes* mosquito, with an estimated 96 million symptomatic cases reported annually and an estimated 40,000 deaths [43]. Other viral mosquito-borne diseases include Zika, chikungunya, yellow, West Nile, Japanese, and tick-borne encephalitis [43]. The 2023 *Lancet* Commission report concluded that the prevalence of climate-sensitive infectious diseases, including vector-borne diseases, continues to rise [19]. Because the incidence and geographical distribution of malaria are climate-sensitive, the transmission season for malaria has lengthened in several regions, particularly in Africa and South and Central America [19]. Controlling vector-borne disease outbreaks requires eliminating or treating stagnant water, stabilizing ecosystems by reducing greenhouse gases,

preserving forests, improving infection surveillance systems, and educating healthcare workers and populations on preventing exposure to and controlling vectors [43].

## Flooding, Water-Borne, and Food-Borne Diseases

Climate change and global warming are associated with increased frequency of heavy rainfall events and flooding [15]. In developing countries, flooding is associated with an increased risk of vector-borne diseases and diseases due to contaminated water [15]. Until recently, flooding in developed countries did not pose an infection risk, but increased severe floods have compromised water sources by overflowing from sewage systems and drains [15]. Flooding also leads to contamination of underground drinking water sources and deterioration of surface water, such as rivers and lakes, which can affect the health of people engaged in recreational water contact [15,16].

Increased temperatures have resulted in outbreaks of infections due to exposure to water-borne and food-borne pathogens due to fecal contamination of drinking water and seafood [16]. Fresh produce, such as salads and vegetables, are irrigated or processed with water that can be contaminated, resulting in outbreaks of food-borne infection [15,16]. If climate changes continue, additional improvements in infrastructure, land use, and control of water distribution will be required to prevent food-borne infection from water-borne contamination [16]. Also, advances in monitoring and surveillance of water supplies and food are needed to improve early warning and prevention systems, which will require improving current public health infrastructure [16]. The 2023 Synthesis Report (SYR) from the UNIPCC includes recommendations to improve health by reducing food loss and waste, increasing the biodiversity of food sources, providing clean sources of water, and reducing exposure of water and sanitation systems to the effects of extreme weather events, including the impact of flooding [44].

## Climate Change and Mental Health

The consequences of climate change affect the mental health and well-being of individuals, societies, and populations who may be interdependent on exposure to stressors in society and the environment [18,45]. Social stressors can range from anxiety regarding the unknown in areas at risk from flooding and drought or physical disruptions to the home environment to lack of employment or access to health care [45]. The combination of social and environmental stressors can produce adverse mental health and reduce well-being, resulting in anxiety and depression, post-traumatic stress disorder (PTSD), impaired sleep, and drug or alcohol abuse [18,45]. Forced migration due

to climate change can result in significant mental health consequences [45]. Approaches to reduce stressors that impair mental health include education on preparedness for potential climate change-related events, increased resources for people or households experiencing poor health and poverty, and continued and increased efforts to reduce greenhouse gas emissions [45].

## Raising Global Awareness of Climate Change and Health

The United Nations Framework Convention on Climate Change (UNFCCC) is an initiative to negotiate agreements between nations to limit climate change and the associated physical, economic, and health risks [46]. The UNFCCC report is published quarterly, with the most recent update published on 29 May 2024 [46]. The UNFCCC has identified Nationally Determined Contributions (NDCs) that aim to keep national emissions in check and a goal of a 1.5°C temperature increase [46]. In 1968, the United Nations (UN) Environment Programme and the World Meteorological Organization established the Intergovernmental Panel on Climate Change (IPCC), which is now a UN intergovernmental body that aims to advance scientific knowledge about climate change due to human activities [44]. The 2023 synthesis report (SYR) from the UNIPCC aimed to recognize the interdependence of climate, ecosystems, biodiversity, and human societies to identify and emphasize immediate risks and options to address global climate change [44]. The UNIPCC SYR assesses climate change to 2100 and beyond and has evaluated long-term impacts, risks, and costs in adaptation and mitigation [44].

The recent concept of 'exposure pathways' identifies that climate change's biological, chemical, or physical stressors can differ in time and according to location, severity, and the affected populations [3,47]. Also, the effects of climate change can accumulate over time and result in long-term health and resilience changes or occur simultaneously with compounding impacts on health [3,47]. Effective public health responses to mitigate the risks of climate change are essential to prevent injuries and illnesses and require medical preparedness in the main areas now known (Table 2) [7,10]. Effective public health responses to mitigate the risks of climate change are essential to preventing injuries and illnesses, which requires medical preparedness in the primary key areas of health known to be affected by climate change (Table 2) [7,10].

## Improving Medical Awareness of Climate Change and Health

At the 26<sup>th</sup> United Nations (UN) Climate Change Conference (COP26), held in Glasgow, Scotland, in November 2021, the

WHO established the Alliance for Transformative Action on Climate and Health (ATAACH) [48]. ATTACH has five global health initiatives related to climate change, including providing finance for low-carbon health systems, preparing climate-resilient and low-carbon health systems, improving supply chains, and considering climate action on nutrition [48].

However, concerns remain that not only governments and healthcare providers need to be made aware of the effects and increasing health burden of climate change, but physicians may also need to prepare. In May 2024, Kline and colleagues from Harvard Medical School published details of the proposed implementation and initial evaluation of an integrated undergraduate medical student curricular training framework to prepare future physicians to understand the health impacts of climate change [49]. Medical students collaborated with faculty to integrate climate content into the pre-clerkship curriculum before applying for recognition from Harvard Medical School as a formal curricular theme that included the impact of climate change, air pollution, and the effects of ecological degradation on health and evaluated the program using an eight-item survey at the end of the pre-clerkship curriculum [49]. The study approved a four-year Climate Change,

Environment, and Health curriculum program in January 2023 [49]. The Harvard Medical School initiative is one of the first aimed at supporting future physicians' practical training to respond to the impact of climate change on patient health [49].

## Conclusions

Climate change profoundly affects the frequency, location, and intensity of heat waves, wildfires, storms, floods, and hurricanes. These extreme climate change events continue to create disease burdens and unique health risks for all populations, but mainly for individuals with chronic medical conditions. The main question facing humankind is whether climate change and these environmental and health consequences are foreseeable and preventable. It is long overdue for knowledge of the effects of climate change on health to be translated into further research, education, and training. There is an urgent need for a global, unified effort to address health problems related to environmental exposures. Collective action transcending national boundaries is crucial for a shared goal of improving health by reducing ecological exposures that lead to avoidable disease and mortality.

## References:

1. World Health Organization (WHO). Climate Change. Key Facts. 12 October 2023. Available from: <https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health>
2. Seneviratne SI, Zhang X, Intergovernmental Panel on Climate Change (IPCC). Weather and climate extreme events in a changing climate. In: Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2023: 1513-766. Available from: [https://www.cambridge.org/core/services/aop-cambridge-core/content/view/5BCB24C5699F1D42B2DE379BDD4E2119/9781009157889c11\\_1513-1766.pdf/weather-and-climate-extreme-events-in-a-changing-climate.pdf](https://www.cambridge.org/core/services/aop-cambridge-core/content/view/5BCB24C5699F1D42B2DE379BDD4E2119/9781009157889c11_1513-1766.pdf/weather-and-climate-extreme-events-in-a-changing-climate.pdf)
3. Balbus JA, Crimmins JL, Gamble DR, et al. 2016. Ch. 1: Introduction: Climate change and human health. The Impacts of Climate Change on Human Health in the United States: A scientific assessment. U.S. Global Change Research Program, Washington, DC. 2016;25-42. Available from: [https://health2016.globalchange.gov/low/ClimateHealth2016\\_FullReport\\_small.pdf](https://health2016.globalchange.gov/low/ClimateHealth2016_FullReport_small.pdf)
4. Guo Y, Gasparrini A, Armstrong B, et al. Global variation in the effects of ambient temperature on mortality: A systematic evaluation. *Epidemiology*. 2014;25:781
5. Sun S, Weinberger KR, Nori-Sarma A, et al. Ambient heat and risks of emergency department visits among adults in the United States: time stratified case crossover study. *BMJ*. 2021;375:e065653
6. Parums DV. Editorial: Climate change and the spread of vector-borne diseases, including Dengue, Malaria, Lyme Disease, and West Nile Virus infection. *Med Sci Monit*. 2024;29:e943546
7. National Institute of Environmental and Health Sciences (NIEHS). Human health impacts of climate change. 2024. Available from: [https://www.niehs.nih.gov/research/programs/climatechange/health\\_impacts](https://www.niehs.nih.gov/research/programs/climatechange/health_impacts)
8. Parums DV. Editorial: Concerns as Highly Pathogenic Avian Influenza (HPAI) virus of the H5N1 subtype is identified in dairy cows and other mammals. *Med Sci Monit*. 2024;30:e945315
9. Intergovernmental Panel on Climate Change (IPCC). Climate change 2022. Impacts, Adaptation and vulnerability. Summary for policymakers. Available from: [https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC\\_AR6\\_WGII\\_FinalDraft\\_FullReport.pdf](https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_FullReport.pdf)
10. US Global Change Research Program (USGCRP), 2016: : The impacts of climate change on human health in the United States: A scientific assessment. Crimmins AJ, Balbus JL, Gamble CB, et al. Eds. U.S. Global Change Research Program, Washington, DC, 312 pp. Available from: <https://health2016.globalchange.gov>
11. Mills NL, Donaldson K, Hadoke PW, et al. Adverse cardiovascular effects of air pollution. *Nat Clin Pract Cardiovasc Med*. 2009;6(1):36-44
12. Alahmad B, Khraishah H, Royé D, et al. Associations between extreme temperatures and cardiovascular cause-specific mortality: Results from 27 countries. *Circulation*. 2023;147:35
13. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. *Lancet*. 2020;396(10258):1223-49
14. Bekkar B, Pacheco S, Basu R, DeNicola N. Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: A systematic review. *JAMA Netw Open* 2020;3:e208243
15. Hunter PR. Climate change and waterborne and vector-borne disease. *J Appl Microbiol*. 2003;94(Suppl):375-465
16. Rose JB, Epstein PR, Lipp EK, et al. Climate variability and change in the United States: Potential impacts on water- and foodborne diseases caused by microbiologic agents. *Environ Health Perspect*. 2001;109 (Suppl 2):211-21. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240668/pdf/ehp109s-000211.pdf>
17. Lake IR, Gillespie IA, Bentham G, et al. A re-evaluation of the impact of temperature and climate change on foodborne illness. *Epidemiol Infect*. 2009;137(11):1538-47
18. Cianconi P, Betrò S, Janiri L. The impact of climate change on mental health: A systematic descriptive review. *Front Psychiatry*. 2020;11:74
19. Romanello M, Napoli CD, Green C, et al. The 2023 report of the Lancet Countdown on health and climate change: The imperative for a health-centred response in a world facing irreversible harms. *Lancet*. 2023;402(10419):2346-94
20. Ritchie H. Global inequalities in CO<sub>2</sub> emissions. *OurWorldInData.org*, 11 Aug, 2023. Available from: <https://ourworldindata.org/inequality-co2>

21. van Daalen KR, Tonne C, Semenza JC, et al. The 2024 Europe report of the Lancet Countdown on health and climate change: Unprecedented warming demands unprecedented action. *Lancet Public Health*. 2024;9(7):e495-e522
22. Wong C. How climate change is hitting Europe: Three graphics reveal health impacts. *Nature*. 2024;630(8018):800-1
23. Haines A, Ebi K. The imperative for climate action to protect health. *N Engl J Med*. 2019;380(3):263-73
24. Hess JJ, Errett NA, McGregor G, et al. Public health preparedness for extreme heat events. *Annu Rev Public Health*. 2023;44(1):301-21
25. Sorensen C, Hess J. Treatment and prevention of heat-related illness. *N Engl J Med*. 2022;387(15):1404-41
26. Leiva DF, Church B. Heat illness. [Updated 2023 Apr 10]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK553117/>
27. Mora C, Dousset B, Caldwell IR, et al. Global risk of deadly heat. *Nat Clim Chan* 2017;7:501
28. Vaidyanathan A, Malilay J, Schramm P, Saha S. Heat-related deaths – United States, 2004-2018. *MMWR Morb Mortal Wkly Rep*. 2020;69:729
29. Hopp S, Dominici F, Bobb JF. Medical diagnoses of heat wave-related hospital admissions in older adults. *Prev Med*. 2018;110:81
30. Layton JB, Li W, Yuan J, et al. Heatwaves, medications, and heat-related hospitalization in older Medicare beneficiaries with chronic conditions. *PLoS One*. 2020;15:e0243665
31. Crichton B. Keep in a cool place: exposure of medicines to high temperatures in general practice during a British heatwave. *J R Soc Med*. 2004;97(7):328-29
32. Rocklöv J, Huber V, Bowen K, Paul R. Taking globally consistent health impact projections to the next level. *Lancet Planet Health*. 2021;5(7):e487-e93
33. Ratter-Rieck JM, Roden M, Herder C. Diabetes and climate change: Current evidence and implications for people with diabetes, clinicians and policy stakeholders. *Diabetologia*. 2023;66(6):1003-15
34. Liu J, Varghese BM, Hansen A, et al. Heat exposure and cardiovascular health outcomes: A systematic review and meta-analysis. *Lancet Planet Health*. 2022;6:e484
35. Liu J, Varghese BM, Hansen A, et al. Hot weather as a risk factor for kidney disease outcomes: A systematic review and meta-analysis of epidemiological evidence. *Sci Total Environ*. 2021;801:149806
36. Vicedo-Cabrera AM. The burden of heat-related mortality attributable to recent human-induced climate change. *Nat Clim Change*. 2021;11(6):492-500
37. Bouchama A, Dehbi M, Mohamed G, et al. Prognostic factors in heat wave related deaths: A meta-analysis. *Arch Intern Med*. 2007;167:2170
38. Rappold AG, Reyes J, Pouliot G, et al. Community vulnerability to health impacts of wildland fire smoke exposure. *Environ Sci Technol*. 2017;51:6674
39. Chen K, Ma Y, Bell ML, Yang W. Canadian wildfire smoke and asthma syndrome Emergency Department visits in New York City. *JAMA*. 2023;330:1385
40. Liao NS, Sidney S, Deosaransingh K, et al. Particulate air pollution and risk of cardiovascular events among adults with a history of stroke or acute myocardial infarction. *J Am Heart Assoc*. 2021;10:e019758
41. Wagner J, Macher JM, Chen W, Kumagai K. Comparative mask protection against inhaling wildfire smoke, allergenic bioaerosols, and infectious particles. *Int J Environ Res Public Health*. 2022;19(23):15555
42. Studholme J, Fedorav AV, Gulev SK, et al. Poleward expansion of tropical cyclone latitudes in warming climates. *Nat Geosci*. 2022;15:14-28
43. World Health Organization (WHO). Vector-borne diseases. 2 March 2020. Available from: <https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases>
44. United Nations (UN) Intergovernmental Panel on Climate Change (IPCC). 2023 Synthesis Report (SYR). Available from: [https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC\\_AR6\\_SYR\\_FullVolume.pdf](https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf)
45. Clayton S, Manning CM, Krygman K, Speiser M. Mental health and our changing climate: Impacts, implications, and guidance. Washington, D.C.: American Psychological Association, and ecoAmerica. 2017. Available from: <https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf>
46. United Nations Framework Convention on Climate Change (UNFCCC). Quarterly Update on climate change. 29 May 2024. Available from: [https://unfccc.int/sites/default/files/resource/message\\_to\\_parties\\_and\\_observers\\_quarterly\\_report\\_1\\_2024.pdf](https://unfccc.int/sites/default/files/resource/message_to_parties_and_observers_quarterly_report_1_2024.pdf)
47. Ebi KL, Balbus JM, Luber G, et al. 2018: Human health. In: Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment. Volume 2. U.S. Global Change Research Program, Washington, DC, USA. Chapter 14. Available from: <https://nca2018.globalchange.gov/chapter/health>
48. World Health Organization (WHO). Final terms of reference of the alliance for transformative Action on Climate and Health (ATACh). 31 August, 2022. Available from: <https://cdn.who.int/media/docs/default-source/climate-change/atach-terms-of-reference.pdf>
49. Kline MC, Malits JR, Baker N, et al. Climate change, environment, and health: The implementation and initial evaluation of a longitudinal, integrated curricular theme and novel competency framework at Harvard Medical School. *PLoS Clim*. 2024;3(5):e0000412