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Published

2023

Journal Title

Journal of Chitwan Medical College

Version

Version of Record (VoR)

DOI

[10.54530/jcmc.1282](https://doi.org/10.54530/jcmc.1282)

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REVIEW ARTICLE

UNVEILING REALITY: AN ENGAGING REVIEW OF CLIMATE CHANGE'S IMPACTS ON HUMAN HEALTH

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Received: 13 Apr, 2023

Accepted: 2 Jun, 2023

Published: 30 Jun, 2023

Key words: Climate change; Health; Impact.

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DOI: <https://doi.org/10.54530/jcmc.1282>

Citation

Yong KH, Gautam A, Chaulagain R, Chu C. Unveiling reality: an engaging review of climate change's impacts on human health. Journal of Chitwan Medical College.2023;13(44):112-8.

ABSTRACT

Background: The phenomenon of global climate change has been observed worldwide. Scientists have determined that the Earth's average temperature has increased by 1°C since the late 19th century. This change is attributed to the increase in greenhouse gas emissions from anthropogenic activities. Aside from rising temperatures, climate change also changes weather patterns and increases the frequency and magnitude of extreme events. This global issue has created long-term anxiety for the public due to negative impacts on ecosystems and human health. Climate change exacerbates health disparities, especially among vulnerable populations. This study aimed to review the current direct and indirect impact of climate change on human health in line with recent developments across the globe.

Methods: A comprehensive literature review was conducted in 2023, identifying and retrieving all related articles published between 2010 and 2023 from electronic databases. Additionally, grey literature from world organisations' websites was also studied.

Results: This review found that climate change directly affects human health through climate extremes, excessive temperatures, and rising sea levels. Climate change also indirectly impacts health through food, clean water, infectious diseases, and migration.

Conclusions: Climate change needs to be addressed urgently, and collective action is needed to mitigate its impact. World leaders and policymakers should find ways to reduce greenhouse gas emissions, transition to clean energy investments and protect the health of vulnerable populations. Lastly, a heatwave is one of the climate-related extreme events that has become more frequent and intense but remains relatively understudied compared to other extreme events. Future climate change research should consider heatwaves and adaptation strategies.



INTRODUCTION

The Earth's climate during this century is changing at an unprecedented rate. There has been a rise in global temperatures as a result of climate change. Global warming is frequently associated with human activities,^{1,2} and human-induced climate change and this is supported by 97% of climate scientists.³⁻⁶ However, a few scholars still assert that human activities do not cause climate change but it is caused by solar cycles, volcanic activity or natural variability.⁷ Global warming has increased temperatures worldwide by 1.0°C from pre-industrial levels, and is expected to reach 1.5°C between 2030 and 2052.⁸ This scenario is alarming, as Intergovernmental Panel on Climate Change (IPCC) highlighted a greater than 50% likelihood of this incident occurring despite the projection being based on the low greenhouse gas emission scenario.⁹

Human activities, such as burning fossil fuels (coal, crude oil, natural gas and wood) for energy and transport, have been the primary source of increasing atmospheric carbon dioxide (CO₂) levels. Ramanathan (2020) calculated that human activities have emitted 2.2 trillion tons of CO₂ since 1750, and 45% of that is still trapped in the atmosphere.¹⁰ In March 2023, the amount of CO₂ exceeded 421 parts per million (ppm) globally.¹¹

It is projected to reach 1,000 ppm by the end of the 21st century.¹² While CO₂ is the major contributor of greenhouse gases, smaller amounts of methane (CH₄), nitrogen oxides (NO_x), halocarbons (RX), and nitrous oxide (N₂O), all drive global climate change and warming.¹⁰

High concentrations of CO₂ have led to a decrease in the pH of the ocean, while also causing it to become more acidic¹³ and the lower atmosphere to become warmer and hotter. McMichael (2013) affirmed that ocean saturation and deforestation have added to the greenhouse warming by weakening terrestrial and marine environments' ability to absorb more CO₂ from the atmosphere.¹⁴ In turn, this leads to an increase in greenhouse gas concentrations in the atmosphere.

Climate scientists have also observed that sea levels have risen because decreasing snow or ice cover in the Arctic regions, melting glaciers and losing Greenland's and Antarctica's ice sheets.¹⁵ This phenomenon has contributed to rising global sea levels. Average sea levels have increased by approximately 23 cm since 1880.¹⁶ This adverse phenomenon threatens biodiversity and shows that global temperatures have risen alarmingly. More importantly, IPCC highlighted that since

1950, global climate change has caused a decrease in the number of cold days and an increase in the number of warm days.¹⁷ According to the WHO's annual report, climate change has resulted an increase in the morbidity and mortality, with the majority in developing countries.¹⁸

In light of the fact that many populations worldwide have been adversely affected by climate change, especially their health, a comprehensive review of recent scientific information concerning the health effects of climate change is urgently needed. The current state of knowledge about climate change impacts on health is reviewed based on a critical analysis of various recent studies. Furthermore, this review provides an additional direction for future research in this area.

METHODOLOGY OF REVIEW

The authors conducted an extensive literature review in 2023 using electronic database such as PubMed, Scopus, Google Scholar, and Web of Science. This study selected peer-reviewed journal articles in English only. In addition, grey literature was researched on the websites of UN, WHO, IPCC, and other related organisations. The literature between 2010 and 2023 was retrieved using a standard search strategy based on single or combined keywords including "climate change", "health", and "impact".

ADVERSE IMPACTS OF CLIMATE CHANGE

Climate change has exacerbated extreme weather and aggravated pollution and air quality in the environment. It significantly and negatively impacts human health,¹⁹⁻²² particularly infants, pregnant women, older adults, malnourished people, and low-income people. Numerous studies have demonstrated that climate change is real and has exacerbated over time.^{1,12,23} However, the effects of climate change are different depending on the region, level of development and healthcare systems. Nevertheless, no country can escape climate change, and the adverse impacts of climate change span from a continuum of direct to indirect.

Direct impacts

Climate extremes

Climate change is expected to alter regional weather patterns. Over the decades, robust evidence associated climate change with the increasing likelihood, frequency, and intensity of extreme climate events, thus, raising growing concern over its adverse impacts on the environment, human health and infrastructures. In the year 2022, many regions experienced extreme climate events such as heatwaves in India, Pakistan and Japan; floods in Thailand, Pakistan, India, Bangladesh, Australia, and Afghanistan; hurricanes in the United States (US) and drought in Cuba, Brazil, China, Europe, the US and Eastern Africa. The impacts of extreme climate events are devastating due to the loss and damage that it causes to human life and livestock, infrastructure damage, the destruction of the

environment and crops, and the production of food and energy.²⁴ A team of researchers reported that climate change increased the frequency and intensity of rainfall events, causing damages of approximately half a trillion USD in the North Atlantic basin.²⁵ Using the review method for some extreme climate events and related indicators, Alimonti and colleagues (2022) found a significant increase in global trend heatwaves for the number of days, maximum duration, and cumulated heat annually, despite little evidence for the heatwave intensity.²⁶

Based on temperature and rainfall data for a 41-year between 1979 and 2019, a study in the US estimated the probability of 100-year events using nonparametric Bayesian methods. The statistical analysis suggested risks of an average 2.1 times increase took place across all months, while a 2.6 times increase occurred between July and October. Meanwhile, the risk of high rainfall was estimated to increase 1.4 times in December and January, but a reduction of 22% in rainfall during the spring and summer months.²⁷ The world literature showed that those affected by extreme climate events have a health risk during or after the event. However, some groups are at higher health risk than others, particularly the underprivileged, the disabled, and those with weak social networks.

Excessive temperatures

Excessive warm and cold temperatures are becoming a serious global health concern. The IPCC reported that the increase of 1.5°C of global temperatures are expected to increase the frequency of heatwaves; the high intensity of heatwaves results in longer warmer seasons and a reduction in the number of cold seasons.²⁸ A rising average temperature in any region will simultaneously increase the number of heatwave events. When the surrounding temperature exceeds the normal human body temperature range between 36°C and 37°C, it can directly affect human physical and mental functioning.²⁹⁻³¹ The cases of illness, injury, and death among infants, the elderly, the disabled, the homeless, low income people, and outdoor workers are anticipated to increase. Jones (2017) argued that heatwave events could directly lead to dehydration and cause an imbalance of minerals, ultimately leading to mortality.³² Numerous established research has demonstrated a sharp increase in weather-related morbidity and mortality under climate change conditions.^{20,33-35} A time-stratified case-crossover study to evaluate the impacts of heatwaves on morbidity in the primary care setting in Flanders, Belgium, from 2000 to 2015 confirmed that heatwaves are positively associated with heat-related morbidities such as heat stroke, dehydration, and orthostatic hypotension.³⁶ A study extracted data from a humanitarian disaster database from 77 countries, with 425 events, from 1999–2018 to estimate the association between extreme weather-related events and mortality. This extensive research identified a positive relationship between mortality rate and extreme weather. More concerning was the mortality rate during the extreme hot season, which was 7-fold higher than during the extreme cold season.³⁷

A recent study also demonstrated that an extraordinarily

cold wave that hit China in November 2021 resulted in extreme temperature decreases, deaths, and damage to road infrastructure.³⁸ Similarly, a study showed that a cold winter of 2021 struck a few nations in central South America (Brazil, Argentina, Bolivia, Chile, Paraguay and Peru), and severely damaged fruit and vegetable harvests and drove up regional food and commodity prices.³⁹ According to the latest IPCC report, the agriculture sector and human health will be severely affected by the global warming heat increase of 2°C.²⁸ Generally, previous studies have shown that excessive temperatures during heatwave events or cold waves are associated with mortality and morbidity.

Rising sea levels

Climate change has a direct impact on the sea level rising. The melting of the Greenland ice sheets and seawater thermal expansion has accelerated the rise of sea level globally.^{40,41} Sea levels have risen by 24 cm worldwide since 1880.⁴² The IPCC projected that the sea level will continue rising along the coastal areas for the rest of the 21st century.²⁸ As a result of this phenomenon, coastal erosion will occur, including land erosion and coastal flooding, especially in low-lying areas. Extreme rises in sea levels results in flooding and erosion of beaches; it alters freshwater salination, damages ecosystems, and hinders drainage.⁴³ Sea level variations are a critical concern to those inhabiting the coastal zone, as rising sea levels may increase the frequency of coastal floods and health risks. The IPCC reported that 700 million people lived in the low-lying coastal zone in 2000 and projected it could reach over one billion in the middle of the 21st century.⁴⁴ The IPCC warned that the potential risk for the frequent occurrence of extreme sea level events is expected to be more prevalent by the end of this century, compared to the previous predictions of one in 100-year floods.²⁸

Giang and Vy (2021) investigated the severity of floods on rice production in Ha Tinh Province, Vietnam, which is affected by sea levels rising. The results suggest an increase in the frequency of extreme precipitation by 5-fold and intensity by 49% by 2050s. Crucially, the rice area is projected to become inundated by 13%, if the 1 meter of water level rises. While the economic loss of rice production is projected to climb over 21% by the 2050s compared to the baseline projection.⁴⁵ Increased frequency of property damages are observed in the 21st century due to rising sea levels and floods, particularly in the coastal areas. In the 21st century (from 2001 to 2018), global economic loss was estimated at more than USD 500 billion, attributing to proximately 2900 flood events.⁴⁶ A research published in 2018 indicated that economic loss from sea level rise or coastal flooding is projected will reduce 0.2% of global real gross domestic product (GDP). Furthermore an estimated 1.5% of the global population would be displaced in the year 2200, and coastal localities will be facing an enormous impact.⁴⁷ Consequently, rising sea levels pose health risks, contributes to death, and has a significant economic impact.

Indirect impacts

Food crises

According to the Food and Agriculture Organization of the United Nations (FAO), food security should consider four dimensions, including the availability of food, accessibility, utilisation and stability of these three dimensions.⁴⁸ Existing research has recognised the adverse effects of global climate change on the agricultural sector, such as farming, fisheries, livestock production, supply chain and prices, consequently raising concerns about food security. This has been supported by some past studies,^{49,50} which demonstrated that frequent droughts and floods in tropical and subtropical areas have caused difficulty for farmers to cultivate their land, thereby directly reducing the productivity of food and decreasing the supply of nutritious food for families. Increasing concerns are raised that the health of vulnerable groups in these areas, such as children, the elderly, the low income, and pregnant women, will suffer from malnutrition and undernourishment. Ultimately, it will lead to rising childhood mortality.

As highlighted by the IPCC assessment report, climate change alters and heightens risks to global food security. At the same time, vulnerable countries and populations are affected with significant risks, including food insecurity and collapse of food structures, loss of income, deprivation of marine and coastal ecosystems, and destruction of terrestrial and inland water ecosystems.⁵¹ Other significant research by the Economic and Social Commission for Asia and the Pacific (ESCAP) revealed that disasters caused by climate change had widened inequalities, especially income, slowed down poverty reduction and permanently impacted the health of the poor and aged population, especially in resource-limited regions, where there are already severe issues with food security.⁵²

Clean water scarcity

Climate change affects the availability of fresh water and clean water globally. It is estimated that global temperatures will rise by 1.4°C-5.8°C and freshwater resources will be reduced significantly.⁵³ Accessing clean water is a fundamental human right and an underlying need for human life and good health. However, for many people worldwide, particularly in developing countries, having clean drinking water is still a faraway dream. Contaminated water and poor sanitation are a recipe for the spread of water-related diseases (e.g., diarrhoea, cholera, polio, and hepatitis A) to populations. This is a significant and critical issue experienced by people in developing countries yearly, who suffer from water-related diseases due to a lack of access to clean water and proper sanitation facilities.⁵⁴ Pandit and Kumar (2015) stated that penetration of physical, chemical and biological pollutants into water bodies have an adverse effect on human health.⁵⁵

Likewise, climate change is anticipated to continuously threaten drinking water quality through multiway, from the emission of greenhouse gases, floods, heavy rainfall, and saltwater intrusion to red tide.⁵⁶ Climate-related extreme events such as severe floods, extreme heatwaves, and violent

typhoons disrupt the water supply facilities, decrease water resources' availability, and reduce drinking water quality. The United Nations (UN) stated that global climate change might limit access to clean and safe drinking water for as many as 2.2 billion people worldwide.⁵⁷ As a result, those vulnerable populations will be exposed to various water-borne illnesses, and their health status will deteriorate.

Infectious diseases

While examining prior infectious diseases and their spread, one can also see an indirect connection between infectious diseases and climate change. Due to deforestation, the natural habitat of wildlife and the ecosystem have degraded, and the interaction of wildlife and humans have become closer and more frequent.⁵⁸ Geographical distribution and degrees of diversity change due to changing environmental conditions and weather patterns,⁵⁹ making it more likely to increase the spread of emerging and re-emerging infectious diseases. Van Hulle (2017) warned that climate change is a health threat due to the risks of re-emerging malaria from malaria-free areas.⁴⁹ MacDonald and Mordecai (2019) estimated that an increase of 10% in the destruction of forests in the Amazon led to a 3.7% increase in malaria incidence in the region.⁶⁰ In addition, Merle and colleagues (2018) argued that the growth of arboviruses such as Zika virus, West Nile virus, chikungunya, yellow fever, chikungunya, and dengue fever is partly influenced by climate change and environmental conditions.⁶¹ Research in Brazil concluded that environmental changes significantly affected human health via infections carried by the chikungunya, Zika viruses, and dengue in Tocantins, Northern Brazil, from 2010 to 2019.⁶²

More interestingly, some studies argued that deforestation has interrupted the whole ecology system, thus leading to widespread infectious diseases. While migration of humans slowly invades animals' habitats, consequently reducing space gaps between human and animal, indirectly increasing risks of infectious diseases transmission.^{59,63} Evidence showed that an increase in mean ambient temperature escalated the widespread viruses spread from wildlife to humans (zoonoses), such as in North American Arctic.⁶⁴ Likewise, recent studies presented that climate change potentially contributed to the emergence of SARS-CoV-2, the contagion responsible for the outbreak of the COVID-19 pandemic.⁶⁵ A comprehensive literature review for Kenya suggested that flooding is identified as the source of infectious disease outbreaks, namely, vector-borne diseases, rodent-borne, and water borne in the country.⁶⁶ A failure to slow down climate change will result in the spread of infectious diseases becoming more widespread, threatening the health of the human population.

Forcing migration

Many reasons trigger people to move from place to place. The reasons can range from searching for a better job opportunity, quality of life, or survival purposes. Recently, growing evidences showed that climatic conditions and changing environment are

drivers of escalating migration.⁶⁷⁻⁷⁰ Sometimes, people choose to move away from climate change vulnerability zones in response to climate change as one of the adaptation strategies, or people may be forced to migrate due to climate-related disasters.^{71,72} Thus, climate change-related migration will likely reshape infectious disease profiles.⁷³

In reviewing an extensive article, McMichael and colleagues (2012) explore the relationships of health impacts for different types of migration due to climate change. They argued that forced migration due to climate change is more likely to associate with adverse health impacts. However, the potential of minimal health risks or even health gains were linked with migration as an adaptive strategy.⁷⁴ In some relevant studies, Desai and colleagues (2020) analysed the association between infectious disease outbreaks and forcibly displaced populations using ProMED reports from 1996 to 2016. The results confirmed a positive relationship between infectious disease outbreak events and the forced migration population. In an interesting statistic, 63% of all infectious disease outbreak events (including cholera, measles, dengue and others) are caused by a disease acquired in the host countries.⁷⁵ As a result of climate change, forced migration is indirectly linked to health risks facing the populations of host countries.

CONCLUSION

Most climate researchers blame human activities for causing concentrations of greenhouse gases to increase in the atmosphere. It has accelerated the global climate change and is becoming the most threatening global issue. This review presented mount evidence that climate change has created multi-faceted risks to human health directly and indirectly, particularly in vulnerable populations. Although world organisations spend millions of dollars discussing and formulating policies to curb climate change yearly, the collaboration between the world nations to tackle climate change issues is still fragile. Therefore, more urgent, and constructive actions need to be taken by world leaders in order to mitigate and deal with the effects of climate change. It is imperative that every country invests in clean energy and make an active policy to halt the acceleration of climate change for the sake of future generations.

Due to climate change, heatwaves are increasing and distributed unevenly across the globe. The adverse effects of heatwaves on the global community are substantial. However, emergency management studies and policy formulation on natural hazards such as earthquakes, landslides, tsunamis, floods, and hurricanes have attracted more studies than heatwaves worldwide, even though heatwaves can cause high levels of human mortality and devastate lives. However, heatwaves are often underestimated, and their impact are frequently not considered in public policies. This is because heatwaves can be difficult to predict and often go unnoticed until it is too late. Considering this, future research should focus on heatwaves as an extreme climate-related event that impacts human health, and its adaptation strategies.

ACKNOWLEDGEMENT

We would like to thank Dr. Yen Nee Teo from the National University of Malaysia for her comments and insights. Lastly,

we gratefully acknowledge the assistance of Dr. Sarah Dyer from Griffith English Language Institute, Griffith University, Australia for proofreading the manuscript.

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