Eco. Env. & Cons. 30 (January Suppl. Issue) : 2024; pp. (S162-S168)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i01s.031

A review on impacts of climate change on human health

Aheli Majumder*[1], Aishwarya Saha[2] and Gopeswar Mukherjee[3]

School of Medical and Allied Health Sciences, Brainware University, and Guest Lecturer, Department of Zoology, Scottish Church College.

(Received 19 June, 2023; Accepted 16 August, 2023)

ABSTRACT

In the recent decades, studies have revealed that climate change has an adverse effect on human health. According to IPCC, the global average temperature is predicted to increase upto an additional 2.8 to 4.6 degree celcius. This change in climatic condition is an outcome of trapping of the greenhouse gases in the earth's atmosphere, due to which humans are becoming more susceptible to diseases associated with heat. For instance, heat stroke, skin disease, wheezing, asthma, etc are becoming more prevalent as well as increase in the growth of harmful climate sensitive vectors like mosquitoes are also seen. Apart from physical health, mental health disorders like mood disorders, anxiety, diminished mental capacity, depression, etc are also thought to be surge due to extreme climatic conditions. As the problem is getting more serious with time, more and more countermeasures needs to be taken by the government like reduction in fossil fuel consumption and finding its replacement with effective renewable energy, like wind, solar energy, etc. Moreover, the common people should be educated more to adapt to these adverse climatic changes as a way of survival. The present review elucidates the correlation of climate change with quite many health issues and the need of taking serious action.

Key words *: Climate change, Global warming, Human health.*

Introduction

According to the U.S Environmental Protection Agency (EPA), climate change is defined as "any substantial change in measures of climate (such as temperatures or precipitation) lasting for an extended period (decades or longer). Climate change may result from natural factors and processes or from human activities".Global warming caused by the accumulation of greenhouse gases and carbon dioxide that trap the heat in Earth's atmosphere thus driving the climate change. Climate modelling are an important tool nowadays for climate change projections. The National Research Council states that "there are still some uncertainties, and there always will be in understanding a complex system like Earth's climate. Nevertheless, there is a strong, credible body of evidence, based on multiple lines of research, documenting that climate is changing and that these changes are in large part caused by human activities".

As far as the impact of climate change on human health is concerned, not only the exposure and vulnerability of populations, countries and individuals, but also their ability towards adaptation and resilience is important. The potential of developing climate change impacts, exposures, and vulnerability indicators (CCIEVIs) strongly suggests that it could serve as a strong pillar of new public health that will safeguard and help in global wellbeing in the coming decades.

Climate change and our planet earth

Since the end of the 19th century, greenhouse gases including carbon dioxide, methane, and nitrous oxide have increased due to human activity, which has raised the planet's average temperature. The effects of rising temperatures include soil degradation, loss of agricultural land productivity, desertification, loss of biodiversity, degradation of ecosystems, reduction in freshwater resources, acidification of the oceans, disruption and depletion of stratospheric ozone, and others. The global average surface temperature has increased by 0.6 °C since the late 1950s.All of these have an effect on people's health, leading to non-communicable diseases such injuries sustained in natural disasters, starvation during famines, and higher mortality during heat waves due to complications in chronically ill individuals. Since the start of the Industrial Revolution, the atmospheric concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) have increased by 47%, 156%, and 23%, respectively . Since 1850, the last 30 years have been the warmest time on record coinciding with the extraordinary release of greenhouse gases.

Through complex pathways, the Earth's climate system has been impacted by the warming atmosphere and ocean over time, upsetting the natural order and causing climate perturbation and natural disasters, such as more frequent extreme temperature events (ETEs), droughts, and floods over the past few decades (Langsdorf *et al.,* 2022). Since it has an impact on both the physical environment and ecosystem as well as how they interact with people, climate change has been identified as the single greatest threat to global health in the twenty-first century. The health effects range from communicable diseases brought on by poor hygiene and an overabundance of germs to early fatalities from natural disasters. According to a multi-nation research, climate change causes an additional 400,000 fatalities annually and is expected to cause 700,000 deaths annually by 2030. No of their age or socioeconomic background, all populations at low to high altitudes and in low to high income countries are at risk from climate change (Zhao *et al.,* 2022).

Scientists have been attempting to comprehend the processes connected to environmental elements that cause climate change since the 1970s. With clear regional effects like heat waves, floods, and droughts, our climate is changing. Human actions have changed the composition of the atmosphere, creating a greenhouse effect that causes global warming.

In the future, widespread emergencies are anticipated to be brought on by global warming. When extreme weather occurrences have an effect on particular areas, these emergencies are actual phenomena. These occurrences include severe droughts, wildfires, winter storms, extreme snow, and severe CAPE (convective available potential energy) thunderstorms (supercells, derechos, and tornadoes). Extreme heat (increased global mean surface temperature, heat waves); climate change-related water disasters (CCRWDs); sea level — flooding, hurricanes, and coastal storms; and droughts; wildfires; are also included. Every weather event gets impacted by the climate change.

Furthermore, the greenhouse effect has already changed the dynamics of the world's climate. A vast amount of information supports that anthropogenic activity is responsible for extreme events, such as the heat waves in Europe and Russia (Christidis *et al.*, 2015), and the devastating floods in Pakistan. Models on how global climate has evolved throughout the eras can be useful in order to give a context to current extreme events Such studies have increased over the past decades. Historical models and earth surface temperature readouts suggest that there is a strong connection between anthropogenic warming and the increased persistence of extreme weather.

Due to changes in air circulation, atmospheric humidity, and general thermodynamic parameters, there is a strong statistical correlation between anthropogenic activity and the current minimal extension of Arctic glaciers. Authors are convinced that some severe events, most notably heat waves and extreme precipitation, would become more frequent as a result of global warming. Extreme climate events are occurring more frequently and with more intensity than ever before in human history The issue is still up for debate, and despite significant advancements, it has been challenging to accurately analyse local occurrences and weigh all of the associated thermodynamic processes.

Socio -economic impacts

From socio-economic point of view, with increasing population and consequently food demand, "climate change could result in an increase of 20% of people at risk of chronic hunger". There is possibility of decreased food quality and production due to

changing precipitation patterns, temperature extremes, increasing carbon dioxide and ozone levels, increase in greenhouse gases and other climatic changes in many parts of the world. Access to groundwater sources in dry subtropical sources may be limited by climate change which will increase the competition for portable water.

Additionally, effects of climate change like droughts and soil drying out could be amplified, especially in rural areasand result in difficulties with farming, starvation, and forced migration ; the ensuing overpopulation of coastal and delta areas could also result in physical illness from vector-borne diseases. Ecosystems with less biodiversity may be at risk from global warming, which could also affect fishing and hunting practises. Famines may also result from anomalous insect populations, increasing pesticide use, or the introduction of genetically modified organisms (GMOs) in combination with a decline in biodiversity. Due to the effects of climate change, 80 percent of the world's population is impacted by food and water insecurity.

In 2020, 720 to 811 million people are predicted to be hungry. As a result, there is a threat to human health because there are insufficient nutrients to support life or because people are more vulnerable to infectious diseases. By 2050, climate change will decrease the amount of food available globally per person by 3.2%, leading to an increase in mortality of 529,000 people worldwide as a result of dietary and weight-related changes. Additionally, a decrease in food production results in a greater usage of pesticides, herbicides, and fertilisers, which further contaminates the land and water (Zhao *et al.*, 2022).

Climate change and human health

In the past few decades, the pervasiveness and severity of infectious diseases, asthma, several kind and intensity of allergies have increased worldwide. There can be several reasons that have impacted an organism including plants and animal health in various ways. For example, increased pollution and population, urbanization, frequent wildfires, increasing temperatures, biodiversity and habitat loss have led to climate change which has negatively impacted the human health in many ways (Bekkar *et al.*, 2020; Agache *et al.*, 2022). A. Respiratory disorders.

Respiratory Disorders

Ozone is a greenhouse gas which has both helpful and harmful effects. It causes irritation to the respiratory system causing increased mortality. Accord-

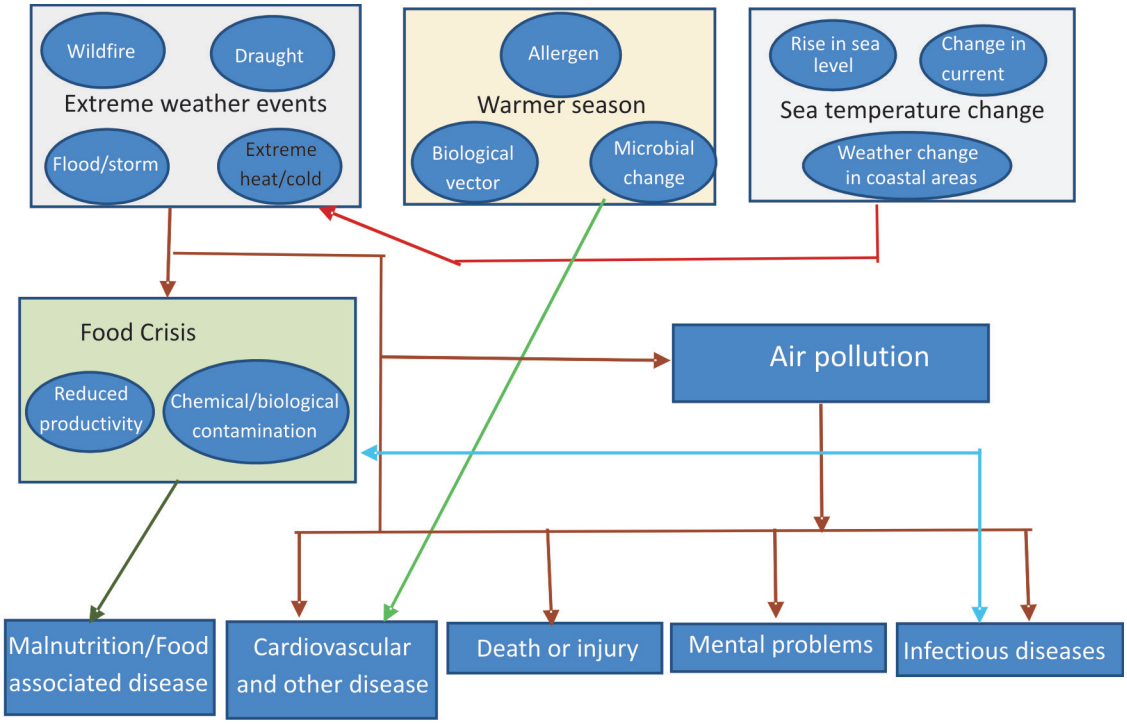

Fig. Effects of Climate Change on Human Health

ing to some evidences from studies, the higher level of ozone concentration is related to respiratory related emergencies by decreasing lung function in certain cases.

The relationship between air pollution and human health may be influenced by climatic conditions (Fann *et al.*, 2021). Air-stagnation events prevent the dilution and dispersion of air pollutants, whereas rainfalls hasten their deposition. High temperatures encourage the chemical transformations of some air pollutants (such as the photochemical production of ozone). A higher yearly temperature in high latitude regions may lead to more days with an ideal temperature, which will encourage outdoor activities and expose people to air pollution for longer periods of time. On contrary, frequent downpours will lead to more time spent indoors, limiting exposure to outdoor air pollution but possibly enhancing the impacts of indoor air pollution. Some investigations suggested that PM10, sulphur dioxide, and nitrogen dioxide have worse health consequences on chilly days, but other studies found the contrary. In addition to its involvement in global warming, air pollution can have a substantial impact on regional climate through aerosol direct effects (such as scattering or absorbing heat) and aerosol indirect effects (such as contributing to cloud formation) (Hong *et al.,* 2020;Zhao *et al.,* 2022).

The distribution, growth, toxicity, and persistence of harmful algal blooms (HABs) along some coastlines are all influenced by high sea surface temperatures.

Vector Borne Diseases

From the taxonomic point of view, studies have been done mainly on pathogens like virus, bacteria with their transmission types like waterborne, vector, food and impact of climatic hazards like global warming, flood, drought etc. With continuous studies it has been found that there are potentially large number and types of interactions in which climatic conditions can affect pathogenic diseases also known as 'viable' interactions (Mora et al., 2022). Growth of harmful climate-sensitive vectors like mosquitoes, ticks are also favoured by warmer climate and changing rainfall patterns which will ultimately result in increase in diseases like dengue fever, malaria, etc.

Malaria is a vector borne disease known to spread only in malaria prone areas for many decades, but recently due to increasing temperature, it is predicted that malaria will be soon spread within the bordering regions which are presently too cold for transmission, surrounding the current malaria areas. But in case of malaria, there are other non-climatic factors like demographic information, use of land, measures of control etc which are to be considered to correctly resolve the effect of climate change on malaria. Another important disease which is also vector-borne, communicable and mainly prevalent in South Africa is Cholera. Climate change induced change in rainfall and temperatures is also likely to affect the transmission of cholera apart from the non-climatic factors like population and lack of proper hygiene and sanitation (Dianati Tilaki *et al.,* 2021).

Research suggests that over half of human pathogenic diseases can be promoted by climate change for example increased emission of greenhouse gases is indirectly aggravating human pathogenic diseases, though the extent to which humans are vulnerable to climate-induced pathogenic diseases is not yet fully quantified (Mora *et al.,* 2022).

With the huge effects of COVID-19, it can clearly be understood that these types of harmful pathogenic diseases not only have detrimental health issues but also causes a havoc on the socio-economic condition of the countries concerned. Ebola HIV, Dengue, Malaria- there's no lack of examples of harmful diseases that have caused huge death toll and have affected the areas tremendously. More than 1000 different pathways have been discovered by which the various climatic hazards have aggravated various pathogenic outbreaks via various types of transmission (Mora *et al.,* 2022).

Infectious illness outbreaks linked to extreme weather events and changes in infectious disease distribution are two effects of climate change scenarios. Leptospirosis, campylobacter infections, and cryptosporidiosis incidences are on the rise following floods.Water heating is impacted by global warming, which increases the spread of water-borne infections. Because they spend a large portion of their life cycle in a cold-blooded host invertebrate whose temperature is similar to the environment, pathogens spread by vectors are especially vulnerable to climate change. An environment that is warmer offers better chances for the vector to survive and complete its life cycle, even hastening it as in the case of mosquitoes.

Because public facilities were destroyed during floods, the danger of water- and vector-borne dis-

eases increased. Intense precipitation and retreating floodwater created breeding grounds for disease vectors, aiding in the spread of West Nile, malaria, dengue, and yellow fever (Tiu *et al.,* 2021). Following floods, there were also reports of infections of the ears, eyes, nose, skin, respiratory, and gastrointestinal systems.

Colder climates have seen an upsurge in tick-borne diseases in recent years because higher temperatures hasten the tick's life cycle, egg production, density, and spread. Both in terms of geographic extent and altitude, tick-infested areas and the diseases they can spread have grown.

A high sea surface temperature is expected to hasten the spread of waterborne diseases such Vibrio cholera, vulnificus, and parahaemolyticus along coastlines. Eating tainted seafood puts you at risk for diseases like diarrhoea, septicemia, and even death (Zhao *et al.,* 2022).

Mental disorders

The significance of environmental factors in psychiatry is rising as a result of birth abnormalities, hinder neurodevelopment, even precipitate endogenous mental disorders, and awaken neurological and psychosomatic illnesses. Strong events caused by the climate can have catastrophic effects on human societies.

As seen by tornadoes, floods, and droughts, disasters produce a distinct type of psychological and psychopathological discomfort from regular seasonal weather fluctuations. Other climatic catastrophes, like as ocean acidification, acid rain, superfog , glacier melting, and biomass extinction, which are frequently ignored in studies on the mental health of populations exposed to them, may also have a greater effect on mental health. Although psychiatry has just lately begun to address climate change, there is still a dearth of particular literature that specifically links climate events to psychiatric problems.

Conclusion

Saving valuable lives from the effect of climate change

Establishment of relevant models and study of complex pathways by which climate change creates an impact on human health are necessary steps towards guiding people to adapt to climate change and to protect their own health. Global warming is putting human health at risk and for that reason international cooperation and exchanges which includes governmental and non-governmental cooperation should be carried out to strengthen our ability to resist climate change and benefit human health. Apart from this, a global environment surveillance system should be established as an effective measure to eliminate impact of climate change on human health.

Government should also improve and formulate the climate related policies and regulations, specifically targeting two points:

- Reduction in fossil fuel consumption and enhancing the efficacy of industries, power stations

Table. Some Vector Borne Diseases Associated With Climate Change

	AGENTS	VECTORS	RESERVOIRS
BACTERIA	1. *Rickettsia spp.*	*Rhipicephalus sanguineus,*	Rodents, dogs, ticks
	2. *Borrelia burdgorferi*	*Dermatocentermarginatus*	Small mammals, birds, reptiles
	3. *Anaplasmaphagocytophilum*	*Ixodes ricinus, I. Persulcatus*	
		Ixodes Ricinus	Goats, sheep, cattle, migra tory birds
VIRUSES	1. West Nile virus	Mosquitoes: *Culex spp.*	Wild rodents, migratory birds, horses
	2. Rift valley virus	*Culex spp., Aedes spp.*	
	3. Dengue virus	*Aedes albopictus,*	Cattles
	4. Yellow fever virus	*Aedes aegyptiAedes aegypti*	Monkeys, humans
	5. Chikungunya virus	*Aedes albopictus, Aedes aegypti*	Monkeys, humans
	6. Tick-borne encephalitis	*Ixodes*	Humans
	7. Zika virus	*Aedes spp.*	Small mammals, birds, reptiles
			Humans, primates
PARASITES	1. *Plasmodium spp.*	*Anopheles spp.*	Humans
	2. *Leishmania spp.*	*Phlebotomus papatasi*	Dogs, foxes, rodents

- As replacement for fossil fuels, more effective renewable energy like waves, solar energy, wind should be developed and deforestation should also be prohibited to maintain the required species diversity in nature.

In the IPCC Working Group II Report, though the potential impact of heat-stress induced mortality is considered, it is not given much importance much like the problem of vector-borne infectious disease where insufficient treatment is given. This is because the IPCC gives selective importance to only the UV-B exposure and related problems. The EPRI review also identify that IPCC has failed to consider and evaluate the regions where global warming may actually improve health like the places where global warming can cause the winter weather to be less severe. But the main problem remains that the main focus of research has always been the heat stress related diseases whereas the infectious disease problems have been neglected.

Despite the fact that the health effects of climate change have been extensively documented, the data to until has mainly concentrated on health outcomes linked to specific unique climatic conditions.For instance, earlier research has shown that heatwaves may increase the death rate for both cardiovascular and respiratory conditions. Few research, however, have examined the interplay of various climatic variables with other non-environmental factors and how these have an additional impact on human health. Understanding the routes is essential for creating mitigation and adaptation plans as well as for determining how climate change affects human health. 2020's average global surface temperature is 0.94 degrees Celsius higher than it was between 1951 and 1980. Due to climatic and natural anomalies brought on by global warming, there may be an increased risk of certain health effects as a result (Zhao *et al.,* 2022).

There are numerous ways to get the co-benefits of mitigation efforts for health. For instance, encouraging cycling or walking improves human health by boosting physical activity and lowering the burning of fossil fuels, which in turn improves air quality. Through such initiatives, unfavourable health outcomes (such as morbidity and mortality) associated with air pollution (such as asthma), physical inactivity (such as obesity), and traffic noise (such as anxiety) can be reduced (Dedoussi *et al.,* 2020; Zhao *et al.,* 2022).

The adaption strategies may concern- 1) routinely assess health vulnerabilities and adaptation capacities; 2) create and implement an evidence-based adaptation plan for health; 3) improve the climate resilience and environmental sustainability of healthcare systems and facilities; and 4) implement health-promoting interventions in other sectors (Zhao *et al.,* 2022).

Increasing the amount of greenery in cities can help them better absorb heat. By reducing road noise, improving air quality, and offering athletic facilities, green space can also lower the morbidity of several diseases. Additionally, the majority of the structures in metropolitan areas contribute to the urban heat island. Dams and reservoirs can help commercial fisheries, guard against droughts, and shield communities from floods and coastal storms. In order to preserve a more comfortable habitat and ecosystem, various physical-level adaptations not only lessen the effects of specific climatic conditions but also significantly improve human health.(Zhao *et al.*, 2022).

Acknowledgement

We are grateful to Brainware University for giving us the opportunity. We are eternally thankful to Mr. Phalguni Mookhopadhyay, honourable chancellor of Brainware University. We express our sincere gratitude to Dr. Abhishek Jana, Associate professor and H.O.D , Department of Allied Health Sciences for all kinds of support possible.

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