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Climate Change and its Effect on Diseases

Introduction

Climate change – the change in average conditions such as temperature and rainfall across the Earth over a long period of time – is caused by a range of human activities which lead to an increased concentration of greenhouse gases (**GHGs**) in the atmosphere. According to estimates by NASA and the National Oceanic and Atmospheric Administration, USA (**NOAA**) the planet's average surface temperature has risen about 1.62 degrees Fahrenheit (0.9 degrees Celsius) since the late 19th century, as a result of the increased carbon dioxide and other man-made emissions in the atmosphere. Most of the warming has occurred in the past 35 years, with the five warmest years on record taking place since 2010 (2016 was the warmest ever year on record, followed by 2019). From shifting weather patterns that affect food production, to rising sea levels that increase the risk of catastrophic flooding, climate change poses a great threat to human life and habitation.

In the backdrop of the current battle against COVID-19, we attempt to examine another potential threat posed by climate change – the ability to spur the growth and outbreak of infectious diseases around the world. In order to examine the link between climate change and diseases, we have reviewed existing literature and research studies to understand how climate change and the resulting environmental changes (such as increased floods, droughts and other extreme weather events) are providing certain disease causing organisms (such as viruses) and disease carriers (such as mosquitoes) with a more favorable environment in which to thrive, multiply and rapidly spread diseases. This is important as disease outbreaks not only pose a major threat to human health but have a large impact on the economy of countries, especially on socio-economically weaker sections of society.

There are now multiple research studies that have explored the link between climate change and diseases. For example, a study conducted at the University of Colorado Anschutz Medical Campus (discussed in detail later) examined the increase in the incidence of diseases like Zika, malaria and dengue fever in the backdrop of a 2017 earthquake and El Niño event in Ecuador[1] (the **Zika Study**). Another report by the Intergovernmental Panel on Climate Change (**IPCC**) concluded that climate

[1] Sorensen, Borbor-Cordova, Calvello-Hynes, Diaz, Lemery, Stewart-Ibarra, *Climate variability, vulnerability and natural disasters: A case study of Zika Virus in Manabi, Ecuador following the 2016 Earthquake*, GeoHealth, 2017, DOI: 10.1002/2017GH000104.

change would cause increased heat-related mortalities and morbidities, greater frequency of infectious disease epidemics following floods and storms, and substantial health effects following population displacement from sea level rise and increased storm activity. However, it is important to note that while scientists have commented on the link between climate change and diseases in the specific context of each study conducted, they have not drawn a conclusive overall link between the two. The information available is nevertheless useful, as it gives us the ability to predict what could happen if certain specific situations (or something similar) repeat themselves. Finally, we also make brief recommendations on the steps that governments around the world can take to better prepare, predict, respond to, and mitigate the effects of future disease outbreaks that result from climate change.

Climate Change and Diseases

We have studied the link between climate change and outbreaks of infectious diseases from three perspectives:

- Past occurrences of infectious disease outbreaks caused due to climate variability;
- Early indicators of the impact of climate change on currently emerging infectious diseases; and
- Future predictions for South Asia based on available data.

I. Historical Evidence

In this section, we discuss some important past occurrences of climate-change/extreme weather events that have caused either (*a*) an outbreak of, or (*b*) an increase in the rate of transmission of infectious diseases.

El Niño, Earthquakes and Zika

In the Zika Study, coastal Ecuador was struck by an earthquake of 7.7 magnitude, and experienced an exceptionally strong El Niño event at the same time, which caused heavy rainfall and warmer air temperatures. After the El Niño event, estimates from remote sensing data in coastal Ecuador showed that sea-surface temperatures had been higher than average from 2014-2016. While El Niño's are anyway linked to outbreaks of dengue fever by creating ideal conditions for mosquitoes to breed and make copies of the virus, this study found these climatic events leading to a 12-fold rise in the number of Zika cases in the quake zone. This was because of two main reasons:

a) The El Niño along with the earthquake caused not only warmer temperatures and increased rainfall, but devastated the infrastructure in semi-urban and rural areas. This led to an influx of people into the larger cities.
b) In the cities, the earthquake severely damaged the municipal water systems. This forced people to store water in open containers outside their homes, and mosquito larvae an additional habitat to grow in.

The above two factors, along with the pre-existing Zika-conducive climatic conditions, likely caused the sudden spike in Zika cases.

Extreme Climatic Events and Malaria

Malaria is a vector-borne disease whose link to extreme climatic events has been studied in India and other parts of the world. Early last century the river-irrigated Punjab region experienced periodic malaria epidemics. Excessive monsoon rainfall and high humidity levels coupled with extensive farming activities allowed malaria carrying mosquitoes to breeding and survive in standing water. This in turn exposed humans to a greater risk of infection from these mosquitoes. Further, recent analyses have shown that the malaria epidemic risk increases around five-fold in the year after an El Niño event, as these climatic events are also the reason for increased rainfall and higher temperatures. Climate change appears to be increasing cases of malaria in Africa as well[2].

II. Impact of climate change on emerging infectious diseases

Climatic factors can be an important determinant of various vector-borne infectious diseases[3], many enteric illnesses[4] and certain water-related diseases. This relationship between year-to-year variations in climate and infectious diseases seems to be more evident where climate variations are extreme. The diseases are expected to rise given extreme climate events have become more frequent. The two categories of climatic extremes are:

- Simple extremes of climatic statistical ranges, such as very low or very high temperatures; and
- Complex events such as droughts, floods, El-Niño's or hurricanes.

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[2] *Climate change may accelerate infectious disease outbreaks, say researchers*, ScienceDaily, available at https://www.sciencedaily.com/releases/2017/10/171012122835.htm

[3] According to the World Health Organisation, vectors are living organisms that can transmit infectious pathogens between humans, or from animals to humans. Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors.

[4] Enteric diseases are caused by microorganisms such as viruses, bacteria and parasites that cause intestinal illness. These diseases most frequently result from consuming contaminated food or water and some can spread from person to person.

Effect of El Niños/La Niñas

Extreme events like El Niños and La Niñas are likely to increase in frequency and/or amplitude as a result of climate change. This can have impact on the outbreak of infectious diseases for the following reasons:

a) Events like El Niños and La Niñas result in higher temperatures and increased rainfall;
b) Depending upon the climatic zone, changes in temperature and surface water influence the insect vector (mosquitoes, flies etc.) in vector borne diseases[5]. Warmer temperatures enhance vector breeding and reduce the pathogen's maturation period within the vector organism during the process of transmission. Thus, events like El Niños and La Niñas can increase the multiplication of disease-causing organisms, and increase the rate of transmission of the disease to humans;
c) This is supported by historical evidence, which shows how tropical and subtropical regions with higher temperature and rainfall (further intensified by the occurrence of an El Niño event) had an increased number of disease outbreaks. Between 1970 and 1995, the annual number of dengue epidemics in the South Pacific was positively correlated with La Niña condition[6].

Effects of Extreme High Temperature

Scientists have found a correlation between certain diseases with unknown origins and changes in weather patterns like extreme high temperatures. For example, a 2019 epidemic of chronic kidney disease that killed tens of thousands of agricultural workers worldwide, was found only in locations with extreme high temperatures, according to an article published in the New England Journal of Medicine in August, 2019 by researchers at the University of Colorado Anschutz Medical Campus.[7] As per the study, chronic kidney diseases of unknown origin (**CKDu**) primarily impact agricultural workers in hot climates. Sugar cane workers in Central America, who often toil in 104-degree heat in heavy clothing, are victims of the illness. Additionally, it has become the second leading cause of death in Nicaragua and El Salvador, and Guatemala has experienced an 83% increase in the death toll from the disease in the past decade. Additionally, the disease has also started spreading to the USA in places with hotter temperatures like Florida, California, and Colorado's San Luis Valley.

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[5] *Supra* note 3.

[6] Hales S, et al (1996), *Dengue Fever Epidemics in the South Pacific Region: Driven by El Niño Southern Oscillation?* Lancet.

[7] Salas, Solomon, *The Climate Crisis — Health and Care Delivery*, New England Journal of Medicine, 2019; 381 (8): e13 DOI: 10.1056/NEJMp1906035.

Effects of Pollution

Many researchers have been studying the link between the COVID19 pandemic and climate change. While the emergence of the COVID19 virus is believed to be via animal-human transmission and not due to weather patterns, existing climatic conditions have certainly impacted the recovery rate of patients. According to Harvard scientists, deaths due to infection by COVID19 are more likely in polluted regions. For every 1 microgram increase in PM2.5, 15% more deaths occur. In Italy, almost half of the deaths have occured in one of its most polluted regions, Lombardy.

The table below shows the correlation between certain environmental changes, the diseases they may cause or have an effect on, and the causal link between the two, as observed in the various research studies on these topics conducted till date.

Environmental Changes/Human Activities	**Diseases**	**Pathway of Effect**
Building of dams, canals and irrigation networks	Schistosomiasis	Fresh water snails carrying schistosomes that occur in shallow water near the shores of lakes, streams and irrigation channels → human contact.
	Malaria	Standing water is a site for mosquito breeding and survival, exaggerated in places with high humidity → bites by infected mosquitoes.
	Helminthiasis (Worm Infection)	Soil-transmitted parasitic worms are found in areas with moist and warm climates, where sanitation and hygiene are poor → ingestion of eggs/larvae of parasitic worms by humans.
	Onchocerciasis (River blindness)	Running water is a breeding site for blackflies → bites by blackflies infected by the worm that causes the disease.

Deforestation for Agricultural Intensification	Malaria	Intensive insecticide usage in agriculture causing insecticide resistance in malaria mosquitoes → bites by infected mosquitoes.
	Venezuelan hemorrhagic fever	Deforestation and preparation of land for farming caused an abundance of rodents in rural areas of Venezuela → inhalation of droplets of saliva, respiratory secretions, urine, or blood from rodents infected by the virus.
Urbanization, Urban Crowding	Cholera	High population and housing density, along with poor water, hygiene, and sanitation infrastructure leading to increased contamination of water → Ingestion of contaminated water or food by humans.
	Tuberculosis	High population and housing density → increased risk of inhalation of bacteria when someone carrying it coughs, speaks, sneezes, spits etc.
	Dengue	Unplanned or poorly planned urbanization with under-developed sanitation infrastructure and drainage systems, leading to large amounts of standing contaminated water which are breeding sites for mosquitoes → bites by infected mosquitoes.
Deforestation and new habitation	Oropouche	Deforestation in tropical regions causes encroachment of humans into habitat of virus carrying midges and mosquitoes, who in turn acquire the virus from infected sloths → bites by infected insects.
	Visceral Leishmaniasis	Deforestation and building of new human habitats cause encroachment of humans to habitat of infected sandflies carrying the virus → bites by infected flies.

Ocean Warming and Waste Dumping	Red tide	Rising ocean temperatures and dumping of nitrogen-rich waste like fertilizers enable the uncontrolled growth of toxic algae → swimming in contaminated waters and ingestion of contaminated seafood.
Increased precipitation level	Rift Valley fever	Infected livestock such as cattle, sheep, goats etc. → Increased temperatures and rainfall/floods create habitats for mosquitoes that pick up the virus when the bite infected animals (the virus can persist in the eggs of the infected mosquitoes for years even in dry conditions) → bites by infected mosquitoes.
Ozone Depletion	Increased susceptibility to infectious disease, skin related ailments	Increased intensity of harmful UV rays → exposure of humans to UV rays.
Extreme high temperatures	Chronic Kidney disease (CKDu)	Correlation exists but exact pathway of effect is not yet known.

Table 1

Source: World Health Organisation, *Climate Change and Human Health - Risks and Responses*, 2003

III. Predictions for South Asia based on available data

Along with examining the connection between climate change and infectious diseases in extreme weather events that have already occurred, scientists have also been collecting data to develop predictive models for future outbreaks of diseases. In this process, scientists have been able to make certain predictions about future weather extremities and the health and disease risk attached.

Water-borne diseases

In South Asia, scientists predict an increased frequency of floods due to greater intensity of rainfall events and glacier lake outburst floods in mountainous regions[8]. According to a 2013 study published in the Indian Journal of Medical Research[9] (the **2013 Study**), if these floodwaters get contaminated with human or animal waste, the rate of faecal-oral disease transmission could increase, allowing diarrhoeal disease and other bacterial and viral illnesses to flourish. This is of particular concern for South Asia given its limited access to clean water and sanitation.

The 2013 Study also predicts that a warmer climate could lead to increased other water-borne diseases, such as cholera and diarrhoeal diseases such as giardiasis, salmonellosis, and cryptosporidiosis. As ambient temperatures rise, the researchers expect that bacterial survival time and proliferation and thus the incidence of diarrhoeal diseases might further increase.

Malaria

Additionally, malaria - which is already one of the most important vector-borne diseases in India, Bangladesh, and Sri Lanka - could potentially expand its geographical range into temperate and arid parts of South Asia due to changes in temperature and precipitation patterns[10]. For example, in India malaria distribution is expected to expand to higher latitudes and altitudes. According to the 2013 study, currently all of India's population is at risk for contracting malaria except for those in the areas above 1700 m above sea surface.

Human Plague

Finally, the 2013 Study estimates that climatic factors might also influence the transmission of human plague, a bacterial disease carried by rodents and transmitted by fleas. The abundance and distribution of rodent population are largely affected by temperature and rainfall. Given the influence of temperature and humidity on flea survival and development, changes in any of these climatic components may result in changes in plague incidence.
Comment: This is a good section above.

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[8] Cruz, et al., *Climate change 2007: Impacts, adaptation and vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

[9] Ramana Dhara, Schramm, Luber, *Climate change & infectious diseases in India: Implications for health-care providers*, Indian J Med Res. 2013 Dec; 138(6): 847–852.

[10] Hales, Edwards, Kovats, *Impacts on health of climate extremes*, In: Climate change and human health: Risks and responses, Geneva, Switzerland, World Health Organization, 2003, pp. 79–102.

What lies ahead for the world and India?

As the effects of climate change continue to accelerate, so will the risk of disease outbreaks. While countries around the world are making ongoing efforts to incorporate more environment friendly practices and reduce climate change, it is equally important for them to prepare for future disease outbreaks by building the necessary infrastructure to predict, deal with, and minimise the risk to populations from these outbreaks. We will need to first ensure that our public health systems are robust during emergencies. We will also need to integrate environmental information and climate models into public health practice and build early-warning systems focused on vulnerable communities and climate-sensitive diseases[11]. This will allow us to direct critical healthcare resources to the people and places that need them most. In order to build an effective early-warning system governments will need:

- Set up a multidisciplinary assessment team;
- Evaluate risk management adaptation techniques;
- Integrate these techniques into public health;
- Assess the effectiveness of such techniques in different settings;
- Identify and fill key research gaps including modelling of relationships between extreme events and health impacts; and
- Continuously gather and analyse data with respect to climate change and the outbreak of infectious diseases.

There are enough studies to conclude that climate variability has a role to play in either breeding, transmission or expansion of disease outbreaks, which makes it imperative for governments to recognise climate change and its health impacts, act, and make some policy changes like shifting to cleaner and greener sources of energy and other adaptation policies for an effective mitigation and climate conservation strategy. The optimal solution, however, would need governments, society and individuals working collectively – and would need changes in behaviour, technologies and practices to enable a transition to sustainability.

[11] *Health care workers unprepared for the magnitude of climate change: Chronic kidney disease is just one climate-related ailment poised to strike*, ScienceDaily, available at www.sciencedaily.com/releases/2019/08/190822094008.htm.