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CLIMATIC VARIATION AND THE EPIDEMIOLOGY OF INFECTIOUS DISEASE IN INDIA

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ABSTRACT :

In India there is an increase of 0.7 °C temperature in last two decades. There is a changing patterns of heat hazard in India since 1960s, dry years are expected to become drier and wet years wetter. The frequency of draughts, especially in arid and semiarid regions, is expected to increase. Due to climate change India is projected to loose 24.7% of its GDP by 2070. There will be decline in labour productivity due to extreme heat, and rising energy demands are major concerns. Indian climate science experts has shown the significant impact of heat on various sectors and public health. In India, climatologic factors are linked strongly to the epidemiology of Infectious Disease. There is increase in prevalence of infectious Disease not only reflect the impact of Temperature , Humidity, and other weather related phenomenon on pathogens, vectors, animal hosts and Antimicrobial resistance. Hence there is an urgent and long term need of Resources for Surveillance and Systemic Education of clinicians on the Health impacts of climate change. The National Centre for Disease Control (NCDC) in India has made a landmark decision to include climate change and its impact on human health in the medical curriculum for doctors and allied health professionals. India is actively tackling climate change through various government initiatives and policies. The country has committed to achieving net-zero emissions by 2070 and has set ambitious targets for renewable energy capacity and emission reductions. These efforts are guided by the National Action Plan on Climate Change (NAPCC).

Keywords: Global warming, Infectious disease, Vectors, Epidemiology, One Health,

1. CURRENT SCENARIO OF CLIMATE CHANGE IN INDIA

The conspicuous features of climate change in India are from the early 90s, the regional as well as the global records were established over this part of the globe on different time scales. Many catastrophic events are associated with the regional and the global warming under the climate change scenario. In the event of their continuation, there would be severe impact on societal, environmental and Health issues warranting appropriate precautionary measures in near future to safeguard the interest of the vast population of this region. The average temperature in India has risen by around 0.7 °C during 1901-2024. The Frequency of daily precipitation extremes (rainfall intensities >150 mm per day) increased by about 75% during 1950-2018. The frequency and spatial extent of droughts over India has increased significantly during 1951-2015. Sea-level rise in the North Indian Ocean occurred at a rate of 3.3 mm per year in the last two and half decades (1993-2017) The Frequency of Severe Cyclonic Storms over Arabian sea has increased during the post monsoon seasons of 1998-2018.These newer and unexpected trends are emerging as critical research areas. In India most studies are based on the IMD's 100-km gridded observation data, or in some cases, ERA-5 reanalysis data.

Fig.1 Global Average Temperature of Earth 1850-2023
(Land Data from- Berkeley Earth, Ocean Data from- UK Hadley Centre)

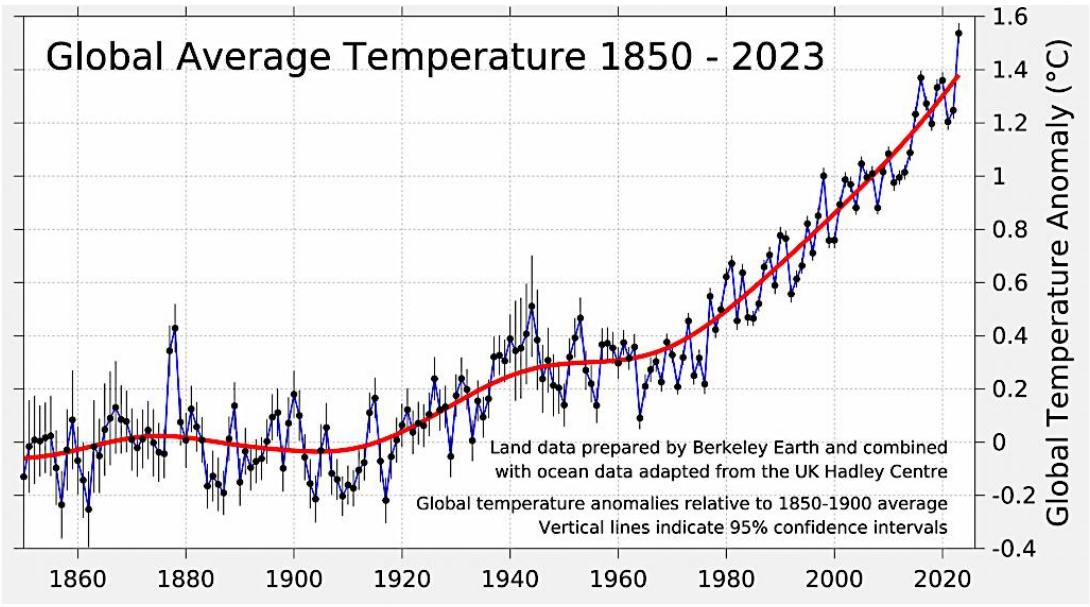


fig.1 In Berkeley Earth's analysis the global mean temperature in 2023 is estimated to have been 1.62 ± 0.06 °C (2.91 ± 0.11 °F) above the average temperature from 1850-1900, a period often used as a pre-industrial baseline for global temperature targets. This is ~0.08 °C (~0.14 °F) warmer than the previous record high observed in 2023. As a result, 2024 is the warmest year to have been directly observed using thermometer measurements, and stands out well-above all previous years.

Fig. 2 Indian monsoon Rainfall 1850-2017

(All-India Summer Monsoon (June-September) Rainfall (AISMR) Anomalies during 1871-2017, Indian Institute Of Tropical Meteorology)

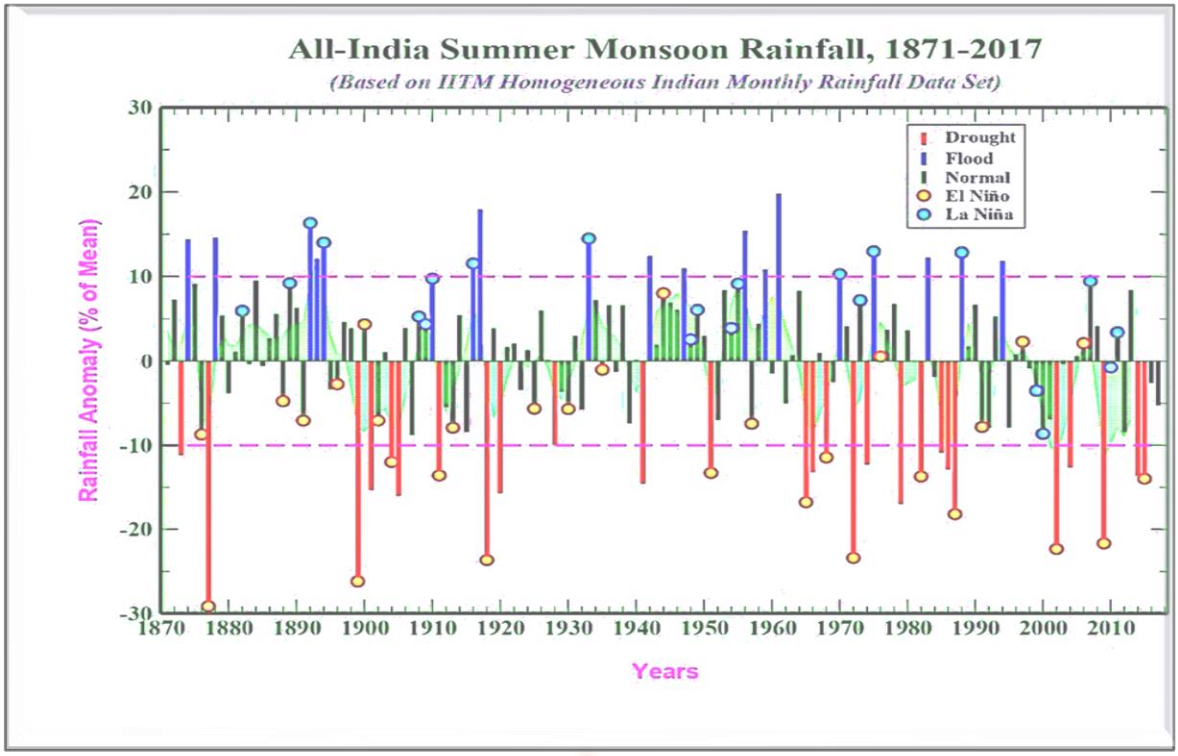


fig.2 This figure shows the evolution of AISMR anomalies with respect to time, expressed as percent departures from its long-term mean, over more than a century in the past. Prediction of the future evolution of the monsoon activity, at least a season in advance, remains a difficult challenge.

*FLOOD YEARS: During the period 1871-2015, there were 19 major flood years, defined as years with AISMR in excess of one standard deviation above the mean (i.e., anomaly exceeding +10%; blue bars above): 1874, 1878, 1892, 1893, 1894, 1910, 1916, 1917, 1933, 1942, 1947, 1956, 1959, 1961, 1970, 1975, 1983, 1988, 1994.

*DROUGHT YEARS: During the period 1871-2015, there were 26 major drought years, defined as years with AISMR less than one standard deviation below the mean (i.e., anomaly below -10%; red bars above): 1873, 1877, 1899, 1901, 1904, 1905, 1911, 1918, 1920, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1986, 1987, 2002, 2004, 2009, 2014, 2015.

Fig.3 Rise in sea level in Indian waters

(Real time Data from ISRO)

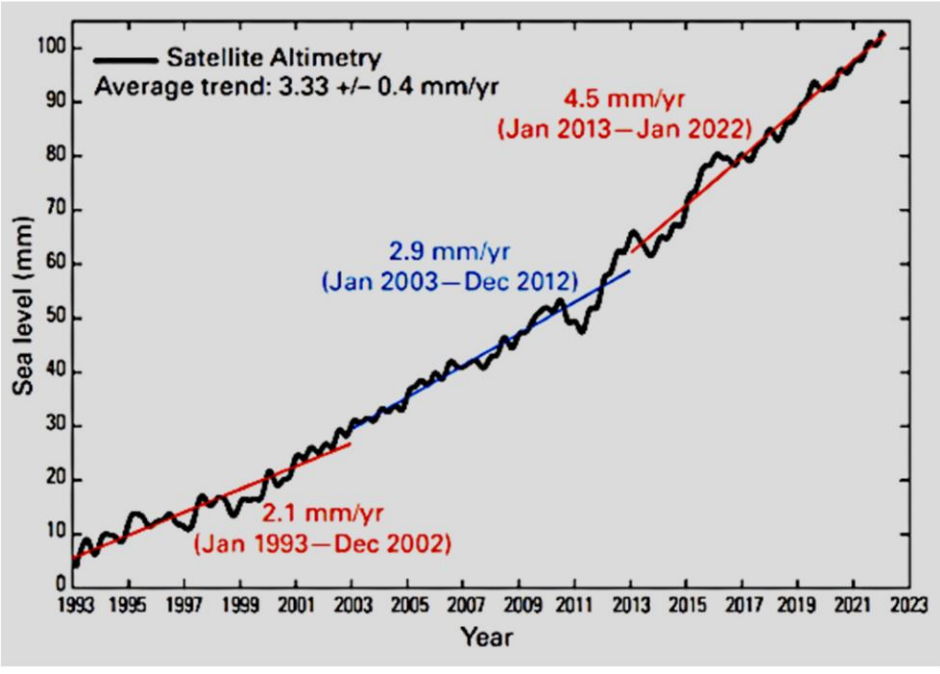


fig.3 It is a 30-year's record of satellite measurements, Sea level rise is estimated to be occurring at a rate of 0.13 inches (3.4 mm) per year Between 2006 and 2015, the average global water level in the ocean increased by 0.14 inches (3.6 millimetres) each year, which is 2.5 times faster than the average growth rate of 0.06 inches (1.4 millimetres) per year during the majority of the twentieth century. According to the WMO, the sea level has risen at a rate of 4.5 mm per year between 2013 and 2022.(Maximum Sea Level Rise (SLR): Maximum SLR over the past three decades (1991–2020) was observed at the Mumbai station (4.44 cm), followed by Haldia (2.72 cm), Visakhapatnam (2.38 cm), etc.
Submergence due to rise in sea levels by 2040: More than 10% of the land in Mumbai, Yanam, and Thoothukudi; 5%–10% in Panaji and Chennai; and 1%–5% in Kochi, Mangaluru, Visakhapatnam, Haldia, Udupi, Paradip, and Puri would be submerged due to rise in sea levels by 2040.)

1.1 Navigating the impact of climate change in India

1. Rise in temperatures and Heat waves

In India almost all land areas are seeing more hot days. The summer season is getting longer and spring and autumn seasons are shrinking. The hottest summer in India was likely experienced in 2024, with record-breaking temperatures and a prolonged heatwave. Mungeshpur in North West Delhi recorded the highest temperature ever in India at 52.3°C Higher temperatures increase heat-related illnesses and can make it more difficult to work and move around. Wildfires start more easily and spread more rapidly.

2. Increased frequency and intensity of Cyclones:

Table. 1 Loss of life in major cyclones in last 50 years

	Name of Cyclone	Year	No. of Deaths
1.	Cyclone Asna	2024	50
2.	Cyclone Fani	2019	53
3.	Cyclone Hudhud	2014	61
4.	Cyclone Andhra Pradesh	1977	20,000
5.	Cyclone Odisha	1999	15,000
6.	Cyclone Bhola	1970	50,000

One of the serious effect of climate change is changes in rainfall pattern. This results in more severe and frequent storms. They cause flooding and landslides, destroying homes and communities, and costing billions of pounds. The highest flood-related displacement in India in recent years was 2024, with 2.5 million internal displacements in Assam. This accounted for nearly half of the 5.4 million total disaster displacements in India during that year. The 2018 Kerala floods are also remembered as a major disaster, with extensive damage and loss of life.

3. Drought and Water scarcity:

In India water is becoming scarcer in central and northern regions. Droughts can stir destructive sand and dust storms that can move billions of tons of sand across continents. Deserts are expanding, reducing land for growing food. Rajasthan is one of the most drought-prone states in India, with very low rainfall, hot and dry climate and arid regions. It receives very less rainfall annually (mostly between 150-750 mm). Large areas of western Rajasthan like Jodhpur and Bikaner are prone to frequent droughts.

4. Rising oceans temperature and oceans level:

These are the Great oceans which soaks up most of the heat from global warming. These warm waters melts ice sheets and raises sea levels, threatening coastal communities. From 1950 to 2020, the Indian Ocean warmed by 1.2°C and the climate models predict a further increase of 1.7°C to 3.8°C between 2020 and 2100, according to Indian Institute of Tropical Meteorology (IITM) . The ocean also absorbs carbon dioxide and more carbon dioxide makes the ocean more acidic, which endangers marine life. It can lead to coral bleaching, destruction of seagrass and kelp forests, and changes in the Indian monsoon.

5. Impact on Biodiversity:

In last 50 years several endangered species in India are facing increased threats due to climate change. These include the Bengal Tiger, Snow Leopard, Asiatic Lion, Great Indian Bustard, and Nilgiri Tahr. Sea turtle and Gangetic dolphins face several challenges from human impacts, and climate change is one more.
Climate change alters their habitats through altered rainfall patterns, rising temperatures, and extreme weather events, leading to food shortages and habitat loss. Some species will be able to relocate and survive, but others will not. Example, In Pakke Tiger Reserve, Arunachal Pradesh, climate change has impacted the breeding period of hornbill species, and fruits are fruiting earlier due to changing weather patterns, forcing hornbills to adjust their nesting periods.

6. Impact on Hydrological Cycle :

Rising Earths Temprature is significantly impacting the hydrological cycle, it causes an intensification and acceleration of the cycle. This leads to increased evaporation and precipitation, resulting in more frequent and intense extreme weather events like a) droughts b) floods c) disturbance in ground water recharge d) water contamination

7. Food Security:

Climate change is disrupting global food production in multiple ways:

(a) Directly: affecting crop yields due to changing temperatures and extreme weather.

(b) Indirectly: low availability of water, diminishing soil health, pests, crop diseases.

Extreme weather events such as prolonged droughts, heatwaves, floods, and unpredictable rainfall patterns have become more frequent, leading to declining agricultural productivity,

Fisheries crops, and livestock may be destroyed or become less productive. Heat stress can diminish water and grasslands for grazing. Changes in climate and increases in extreme weather events are among the reasons behind high food prices, global rise in hunger and poor nutrition.

8. Impact on Human health:

A workshop was held in Goa, India, on 30 August through 2 September 2009, it was cosponsored by the University of Michigan's Centre for Global Health, the U.S. Centres for Disease Control and Prevention's National Centre for Environmental Health, and the Indian Council of Medical Research. Scientists from the cosponsoring institutions, along with other partners from academia, government, and nongovernmental organizations, met under the auspices of the existing Indo-U.S. Collaboration in Environmental and Occupational Health to discuss the current state of the science, identify gaps in understanding, and outline future research directions related to the human health effects of climate change in India. The aim was early prediction and prevention of diseases in India, and discussions touched on the tremendous opportunities and significant challenges associated with designing, initiating, and conducting research, as well as pursuing related public health programming to improve public health infrastructure in the face of climate change.

(a) Heat-related illnesses:

Rising temperatures increase the risk of heatstroke, dehydration, and other heat-related illnesses, particularly among vulnerable populations like the elderly and those with pre-existing conditions.

(b) Respiratory problems:

Changes in air quality due to increased ground-level ozone, PM.2, pollen, Short-Lived Climate Pollutants (SLCPs) and wildfire smoke can exacerbate respiratory illnesses like asthma and allergies, and also contribute to cardiovascular diseases.

(c) Infectious diseases:

Climate change can alter the geographic range and transmission patterns of vector-borne diseases like malaria, dengue fever, and Lyme disease, as well as waterborne illnesses.

(d) Mental health:

Extreme weather events and displacement can cause trauma, stress, anxiety, and other mental health issues.

(e) Waterborne diseases:

Flooding and water contamination can increase the risk of diarrheal diseases and other illnesses related to unsafe drinking water.eg. Typhoid Fever

(f) Impact on child health:

Children are vulnerable to the health impacts of climate change, with increased risk of respiratory illnesses, infectious diseases, heat stroke and malnutrition.

(g) Increased burden on healthcare systems:

Rise in climate-sensitive diseases and injuries will strain India's already inadequate public health infrastructure, leading to overcrowded hospitals and limited access to care.

9. Poverty and displacement:

Climate change increases those factors which either put or keep people in poverty. Floods may sweep away urban slums, destroying homes and livelihoods. Heat can make it difficult to work in outdoor jobs. Weather-related disasters displace 23 million people a year, leaving many more vulnerable to poverty.

Examples of climate-related displacement in India:

(a)Assam:

Several flood events in the Brahmaputra river basin are causing displacement from silt islands and eroding riverbanks, leading to permanent displacement.

(b)Coastal regions:

Sea-level rise and increased frequency of cyclones are threatening coastal communities, leading to displacement and loss of livelihoods.

(c)Sundarbans:

Extreme flooding and erosion are forcing people to migrate from the Sundarbans region.

(d)Kerala and Tamil Nadu:

Climate-related disasters in these states have also led to displacement and migration.

10. Glacier Melting and Water Resources

Himalayan glaciers in India are melting at an accelerated rate due to climate change.

a) water resources:

Glaciers in the Hindu Kush Himalayas and Gangotri regions are a crucial source of freshwater for rivers in India, supplying water for agriculture, drinking, and various other uses. The rapid melting could lead to increased river flows in the short term, potentially causing floods, but also to reduced water availability in the long term.

b) Glacial lake outburst Floods:

Melting glaciers lead to the expansion of glacial lakes, some of which become highly unstable. The outburst of these lakes can cause devastating flash floods downstream.

c) Disasters :

1. A major flood in Uttarakhand, India, in 2013, triggered by a glacial lake outburst, serves as a stark reminder of the potential for devastating consequences from glacier melt.

2. Arunachal Pradesh:

A study found that the Eastern Himalayan state lost 310 square kilometres of glaciers between 1988 and 2020, impacting the water source for over 1.3 million people.

3. Sikkim:

The South Lhonak glacial lake outburst in Sikkim in 2023 resulted in a devastating flood that killed 55 people and destroyed a hydropower dam.

2. ASSESSING THE IMPACT OF CLIMATE CHANGE ON PATHOGENS, VECTORS & HOSTS.

2.1. Effects of climate change on Population Density and Range of Vectors:

(a) Temperature: Rise in temperatures accelerate the development and reproduction rates of vectors like mosquitoes, allowing them to thrive in areas previously too cold for them.

(b) Precipitation: Changes in rainfall patterns, such as increased rainfall leading to flooding or droughts creating stagnant water, can create more breeding sites for vectors.

(c) Extended Transmission Seasons: Hot weather is seen from April to September when vectors are active and capable of transmitting diseases.

(d) Geographic Shifts: Vectors can expand their range into new areas as climate change alters suitable habitats, potentially introducing diseases to regions where they were previously absent.

2.2. Effects of climate change on Animals:

(a) Loss of Habitat:

Rising temperatures and changing weather patterns can make existing habitats unsuitable for certain species. For example, Elephants in Tamil Nadu and Karnataka are increasingly moving into Andhra Pradesh due to habitat loss and climate change, damaging crops and leading to human-elephant conflict. Snow leopards, adapted to high-altitude ecosystems, are facing habitat loss due to glacial melting and changes in vegetation patterns. The hispid hare, inhabiting Himalayan grasslands, is losing its habitat due to climate change and other factors.

(b) Altered Migration Patterns:

Many animals migrate to follow seasonal changes in food availability or suitable breeding grounds. Climate change can disrupt these patterns, leading to mismatches between migration and food sources. For instance, birds may arrive at breeding grounds earlier than usual, but their food sources might not be available yet, impacting their reproductive success.

(c) Changes in Distribution of species:

Some species may be able to adapt to warmer temperatures by moving to higher latitudes or altitudes. However, others may not be able to migrate quickly enough or may face competition from other species in the new areas. This can lead to changes in the distribution of species, with some populations declining or even going extinct in certain areas, while others may expand their ranges.

(d) Impacts on Breeding and Reproduction:

Climate change can affect breeding seasons, egg incubation times, and offspring survival rates. For example, warmer temperatures can lead to earlier hatching of insect larvae.

(e) Ocean acidification:

increased carbon dioxide in the atmosphere, can also impact marine
animals with shells or skeletons, making it harder for them to survive and reproduce.

(f) Increased Disease Outbreaks:

Warmer temperatures can create favourable conditions for the spread of diseases, both among animals and between animals and humans. This can lead to increased mortality rates and further endanger already vulnerable species.

(g) Human-Wildlife Conflict:

As climate change forces animals to move into new areas, they may encounter human settlements, leading to increased conflict over resources. This

can result in damage to crops, livestock losses, and even attacks on humans.

(h) Overall Biodiversity Loss:

Climate change is a major driver of biodiversity loss, potentially leading to the extinction of many plant and animal species. The loss of biodiversity can have cascading effects on ecosystems, impacting the services they provide to humans.

2.3. Effects of climate change on Birds

(a) Changes in migration pattern : Changing temperatures and rainfall affect the timing and routes of bird migrations, potentially disrupting crucial breeding and feeding cycles. For example, the arrival of the Pied Cuckoo with the monsoon is linked to insect abundance, which is affected by rainfall patterns.

(b) Habitat Loss and Degradation: Increased temperatures and changes in precipitation can lead to habitat loss and degradation, shrinking the suitable areas for many bird species. This is particularly concerning for migratory birds, whose ranges may shift and diminish.

(c) Food Availability: Climate change affects the availability of insects, seeds, and other food sources that birds rely on, leading to malnutrition and reduced reproductive success.

(d) Increased Heat Stress: Intense summer heat can cause dehydration and other heat-related illnesses in birds, particularly in urban areas.

(e) Shifting Distributions: Many bird species are predicted to shift their ranges, moving to higher elevations or northward, potentially leading to increased competition and vulnerability.

(f) Reduced Breeding Success: Changes in temperature and food availability can negatively impact breeding success, potentially leading to population declines.

(g) Wetland Degradation: Changes in wetland hydrology due to climate change can negatively affect water birds that rely on these ecosystems.

(h) Vulnerable Species and Regions:

(a) Migratory Birds (b) Species at Higher Elevations (c) Endemic Species : A significant portion of India's endemic bird species are projected to experience reduced climatically suitable areas. **(d) Waterbirds:** Wetlands, crucial habitats for many bird species, are threatened by rising sea levels and changes in hydrological cycles. herons, egrets, cormorants, pelicans, ducks, and various waders like sandpipers and lapwings.

2.4. Human migration due to climate change:

(a) Displacement from Disasters: Extreme weather events, such as floods, droughts, and storms, can destroy homes, infrastructure, and agricultural lands, forcing people to relocate. For example, river flooding in Bangladesh has led to population migration to India.

(b) Impact on Livelihood : Changes in climate patterns, like shifting rainfall or increased temperatures, can negatively impact agriculture and other livelihoods, leading to food shortages and economic hardship. This can make it difficult for people to sustain themselves in their current locations, pushing them to migrate to better sustainable places.

(c) Scarcity of Resources: Environmental changes can lead to water scarcity, barren land, and decreased access to other essential resources, creating competition and conflict over resources.

(d) Sea-Level Rise: Rising sea levels threaten coastal communities, potentially displacing millions of people as their lands become submerged or inundated by saltwater.

2.5. Climate change and Fungus

(a) Fungi are evolving to tolerate higher temperatures, potentially expanding their geographic range and increasing their abi lity to cause infections in previously unsuitable climates. Some fungi are developing the ability to survive at higher temperatures, which could allow them to infect humans more easily as human body temperatures become less of a barrier. Altered weather patterns, including increased frequency and intensity of heat

waves, droughts, and floods, can affect fungal habitats, promoting the spread and survival of certain species. Example, *Coccidioides fungus*, which thrives in hot, dry environments, is expanding its range due to increased drought conditions. *Aspergillus flavus*, a deadly fungal pathogen, is also predicted to spread with climate change. (b) Climate change results in increased CO2 which can alter fungal metabolism, affecting their ability to produce toxic secondary metabolites and potentially enhancing their virulence. (c) Fungi like *Fusarium verticillioides*, a maize pathogen, become more resilient and produce more toxins under high CO2 conditions, leading to increased infection rates. (d) Events like wildfires and floods, intensified by climate change, can increase fungal exposure to humans and animals. (e) Natural disasters can trigger outbreaks of fungal diseases and facilitate the spread of fungal pathogens. (f) Climate change is projected to increase the risk of fungal infections, particularly in vulnerable populations. (g) Fungal pathogens are spreading to new geographic areas, potentially leading to new outbreaks and increased disease burden. (h) Climate change can also affect host susceptibility to fungal infections through impacts on the immune system.

2.6. Climate change and Bacterial life

(a) Gene Expression: Bacteria can alter the expression of specific genes in response to environmental changes, allowing them to adjust their physiology and behaviour.

(b) Mutations: Over a period of time, Bacteria can mutate to provide a selective advantage in the new environment, leading to evolutionary changes.

(c) Shifts: Environmental changes can favour certain bacterial species over others, leads to shifts in the overall composition of microbial spices.

(d) Ecological Impacts: Changes in microbial spices can affect nutrient cycling processes like carbon and nitrogen cycling, which are vital for ecosystem.

(e) Disease: Environmental changes can alter the dynamics of pathogenicity of bacteria, potentially increasing the risk of disease transmission.

3. ASSESSING THE IMPACT OF CLIMATE CHANGE ON INFECTIOUS DISEASES

3.1. Vector-borne diseases

The main factor associated with climate-related spread of infectious diseases is the alteration of vector availability and infectivity. As vectors are cold-blooded animals (ectotherm), vector abundance, survival and feeding activity are expected to increase at higher temperatures (5°C-55°C) Hence, the change in climate particularly global Earth surface temperature, some pathogens would shift or expand to different geographical areas across the world. India is also experiencing rapid ecological changes owing to population explosion, urbanization, development projects, deforestation and human migration affecting mosquito ecology and disease transmission. A study has shown that the distribution of malaria shifted to higher altitudes in Himalayan region on North India. It is the effects of temperature, precipitation, relative humidity and wind on vector mosquitoes make them capable of moving and transmitting in northern planes. Aedes aegypti is prevalent in warm-humid climate zones but now it can be seen in northern most areas due to rise in temperature.

*Limitations: the relationship between climate effects and vector-borne diseases is multifactorial, hence no single factor could be used to accurately predict disease occurrence. Other factors associated with the interactions between humans, vectors and the environment should also be considered.

3.2. Zoonotic diseases

Sever climatic events could also induce the expansion of zoonotic diseases. In particular, extreme seasonal variations in temperature or rainfall could lead to a temporary increase in the availability of food supply to certain reservoir animals, resulting in population explosion. The zoonotic diseases prioritized in India as of 2020 include **Influenza, Anthrax, Japanese Encephalitis (JE), Leptospirosis, Brucellosis, Rabies, Scrub Typhus, and Crimean-Congo Haemorrhagic Fever** (CCHF), India faces a significant risk of these zoonotic disease due to animal population explosion. In last decade in state of Kerala **Malaria**, **amoebic meningoencephalitis**, and now **Nipah**, Kerala has been witnessing outbreaks of several zoonotic diseases. According to experts, dense forest cover, extreme climate change, and the large migrant population make the kerala state prone to such infections.

3.3. Water-borne diseases

1. Extreme weather events related to climate change include an increased prevalence of devastating cyclones, storm surges and flooding. These climatic events facilitate the spread of water-borne diseases by mobilizing pathogens in the environment and compromising wastewater management systems. Primarily due to the lack of clean water for drinking and washing, as it has been reported for cholera, infant diarrhoea, pneumoniae, dengue and malaria. There is a huge inter-state variation in the cases relating to water-borne diseases. Nine states accounted for more than 65% of all the cases reported on diarrhoea and typhoid. Developed states like Karnataka, Maharashtra, Andhra Pradesh, and relatively less developed states like Odisha, UP, Madhya

Pradesh, and Rajasthan are a part of this group.

2. In coastal states like Andrara pradeh ,Karnataka, Kerala, West bengal rising sea temperatures also provide conducive conditions for bacterial growth and expansion. A major concern is the climate change-induced spread of *Vibrio cholerae*, a bacterial species capable of causing cholera pandemics. Viability, growth and survival of *V. cholerae* as well as its interactions with the copepod animal host are increasing with the warming of brackish and marine environments. In Denmark, a study has shown the correlation between *Vibrio* and *Shewanella* infections and coastal summer temperatures. In addition, the pathogenicity of some water-borne bacteria, such as *Shigella*, *V. cholera* and *Salmonella*, is regulated by temperature, typically increasing at elevated temperatures (particularly at around 37C).

4. ANTIMICROBIAL RESISTANCE DUE TO CLIMATE CHANGE

Change in climate in India can significantly worsen antimicrobial resistance (AMR) by creating conditions that favours the spread of drug-resistant bacteria and increase the need for antimicrobial use. Factors like rising temperatures, extreme weather events, and altered rainfall patterns can disrupt ecosystems, contaminate water and food supplies exacerbate the spread of infectious diseases, leading to more reliance on antibiotics and promoting resistance development. Let's look into the details;

(a) Use of Antimicrobial in Disease Prevalence:

1.Climate change is linked to the spread of vector-borne diseases (like dengue fever) and waterborne illnesses(cholera), increasing the need for antimicrobial treatments. 2.Extreme weather events can leads to floods and disrupt sanitation and healthcare systems which leads to disease outbreaks and increased antimicrobial consumption.3.High temperature and more precipitation can alter the distribution of pathogens, potentially introducing antibiotic-resistant strains to new areas.

(b) Enhanced Microbial Adaptation and Resistance:

1. Warmer temperatures can accelerate the mutation rates of bacteria, potentially leading to faster development of resistance. 2. Exposure to sub-lethal doses of antimicrobials, potentially due to improper storage or inadequate treatment, can drive resistance evolution. 3. Contamination of water and soil with antimicrobial residues from human and animal sources can create selective pressures, favouring resistant bacteria.

(c) Disruptions to Healthcare and Sanitation:

1. Extreme weather events like storm, cyclone, floods can damage infrastructure, disrupt supply chains for medicines, and overwhelm healthcare facilities, leading to increased risk of infection and reliance on antimicrobials. 2. Flooding and poor sanitation can spread antimicrobial-resistant bacteria and pathogens, contaminating water sources and food supplies. 3. Degradation of medicines due to improper storage conditions (heat, humidity) can reduce their effectiveness and contribute to the development of resistance.

(d) Impact on Agriculture and Food Security:

1. Climate change can affect agricultural practices, potentially leading to increased use of antimicrobials in livestock to maintain productivity and food security. 2.This increased antimicrobial use in agriculture can contribute to the development and spread of AMR in animal populations, which can then be transmitted to humans.

(f) Environmental Factors:

1. Climate change can alter the composition and function of microbial communities in various environments (e.g., soil, water), potentially impacting the spread and persistence of antibiotic resistance. 2. Rising temperatures and changing precipitation patterns can affect the survival and proliferation of resistant bacteria in aquatic environments. 3. Airborne particulate matter (PM2.5) can carry antibiotic resistance genes, potentially impacting human health through inhalation.

5. EMERGING INFECTIOUS DISEASE IN INDIA

5.1. Spillover Events among Animals and Humans

Climate change can disrupt ecosystems, leading to increased contact between humans and animals, and potentially facilitating the transmission of pathogens from animals to humans (zoonotic spillover).

Examples: (a) SARS-CoV-2, the virus responsible for COVID-19, is believed to have originated from zoonotic spillover, and climate change may be a factor in the frequency of such events. (b)Zika virus: An arbovirus transmitted by mosquitoes, causing microcephaly and other neurological complications.
(c) Ebola virus: A severe haemorrhagic fever with high mortality rates, primarily affecting parts of Africa. (d) Lyme disease: A bacterial infection transmitted by ticks, with increasing incidence in many parts of the world. (e) West Nile virus: An arbovirus transmitted by mosquitoes, causing neurological illness in some cases. (f) Avian influenza (H5N1): A highly pathogenic avian influenza virus with pandemic potential. (g) Crimean-Congo Haemorrhagic Fever (CCHF): A tick-borne viral disease, with cases reported in India. (h) Kyasanur Forest Disease (KFD): Another tick-borne viral disease, prevalent in the Western Ghats region of India.

5.2. Globalization and increased travel eg. Zika , COVID-19, Nipah

5.3. Environmental changes eg. Nipah, Hantaviruses, Chikungunya, Human Enterovirus-71, Influenza, Chandipura, Crimean Congo, SARS Coronavirus, Buffalopox, Dengue and Japanese Encephalitis viruses.

5.4. Antimicrobial resistance eg. MDR-TB

5.5. Healthcare-associated infections Healthcare staff faces a real risk for the acquisition of several viral infections, including HBV, HCV, HIV, rubella, viral haemorrhagic fevers (CCHF), encephalitic infections such as rabies and Nipah

6. SURVEILLANCE AND DISEASE CONTROL ACTIVITIES IN INDIA

6.1. Integrated Disease Surveillance Programme (IDSP):

It is a decentralized, state-based surveillance programme in India.
It was launched with World Bank assistance in November 2004 by the Ministry of Health and Family Welfare, Government of India. To strengthen and maintain a decentralized laboratory-based IT enabled disease surveillance system for epidemic-prone diseases to monitor disease trends and to detect and respond to outbreaks in the early rising phase through trained Rapid Response Teams (RRTs).
Programme Components:
a) Integration and decentralization of surveillance activities through the establishment of surveillance units at the Centre, State, and District levels.
b) Human Resource Development: Training of State Surveillance Officers, District Surveillance Officers, RRT, and other medical and paramedical staff on principles of disease surveillance.
c) Use of Information Communication Technology for collection, collation, compilation, analysis, and dissemination of data.
d) Strengthening of public health laboratories.
e) Inter sectoral coordination for zoonotic diseases.

6.2. National Health Programmes:

India implements various national programs for disease control, including those for vector-borne diseases, leprosy, tuberculosis, rabies, and zoonotic diseases.

6.3. "One Health" Approach:

Recognizing the interconnectedness of human, animal, and environmental health, India is increasingly adopting the "One Health" approach, particularly for zoonotic disease surveillance.

6.4. Surveillance Types:

Different surveillance methods are employed, including active surveillance (particularly during outbreaks and for eradication), passive surveillance, sentinel surveillance, laboratory surveillance, and syndromic surveillance.

6.5. Data Management and Analysis:

IDSP utilizes data from various sources, including public and private health facilities, to monitor disease trends and detect outbreaks early.

6.6. Strengthening Surveillance Capacity:

Efforts are underway to enhance emergency management human resource capacity, strengthen emergency operations centers, and improve rapid response teams.

6.7. Public Health Surveillance Goals:

The overall goal is to improve outbreak preparedness for both communicable and non-communicable diseases.

6.8. Antimicrobial Resistance (AMR) Containment:

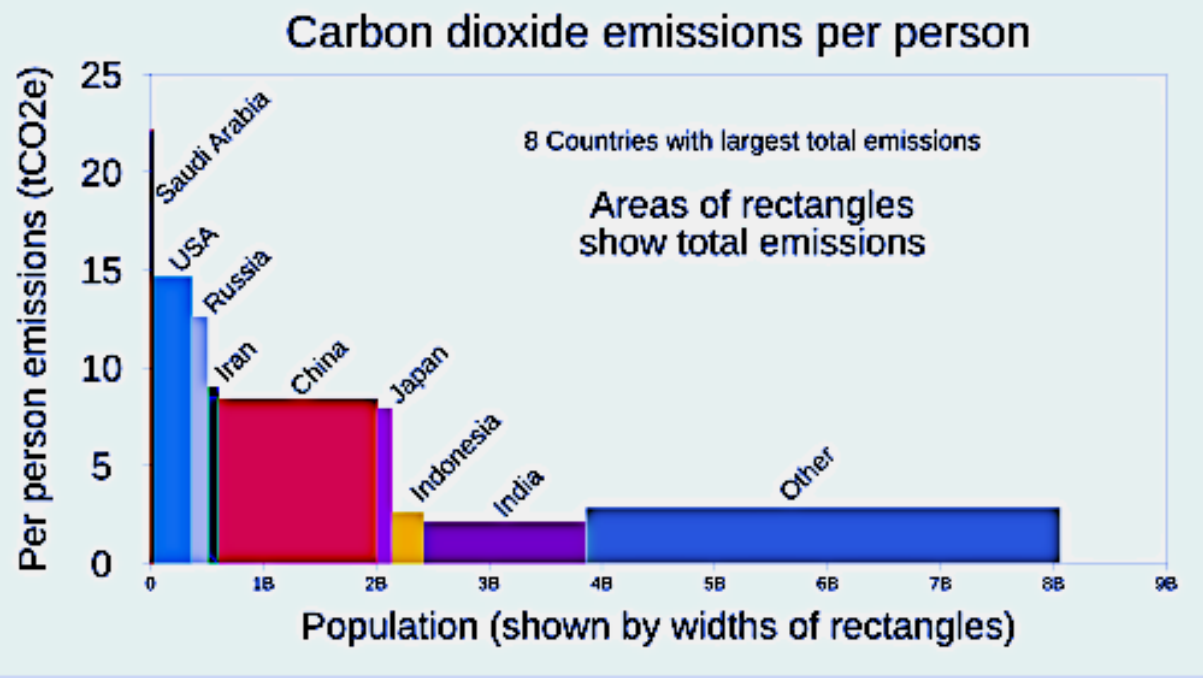
Initiatives include national surveillance networks for AMR, awareness campaigns, and guidelines for the judicious use of antimicrobials.

6.9. Collaboration and Partnerships:

The Indian government collaborates with international organizations like the Centers for Disease Control and Prevention (CDC) to strengthen its health system and address disease outbreaks.

7. A CALL TO ACTION

It is a noteworthy fact that the developing countries are genuinely anxious about the future impacts of climate change. But the reasons regarding their reluctance for not engaging in more ambitious mitigation strategies to regulate their own emissions remains unresolved and the main reason that has been raised before different forums for negotiations on climate change is the equity principle. The developing countries believed it unfair on their part to take up the burden of mitigation similar to the developed countries. It is justified on the ground that the problem of climate change is largely not of their making and therefore it would be unjust to expect mitigation contributions on their part. Indeed, it is the responsibility of the developed countries for their collective contribution of approximately 75 percent of energy-related greenhouse gas emissions since 1840. The per capita emissions of India had always remained significantly below those of the industrialized countries. The per capita emissions of many of the poorest countries is far less than the major industrialized countries like USA, Australia and Canada. It is also true that Asia is emerging as one of the world's largest emitters, but it is also important to note that such a rise in emissions has occurred only in very recent times. They are in fact a byproduct of wide scale improvements in living standards, life expectancy, fall in extreme poverty as well as formal education of its massive population.



The disparities between individual countries are even more striking. In terms of per capita emissions, there are very large inequalities across the world. While in 2024, the per capita emission of CO2 in India is 1.89 tons, it is 14.21 tons per capita in the US, Kuwait 23.99 tons, UAE 21.36 tons. Many of the large annual emitters among the developing countries including India today, were not large contributors in the historical context. In fact, the per capita emission of CO2 in India was 0.05 tons and 8.52 tons in the US during the 1900. This shows that even now countries like India are still far behind the per capita emission of US during the 2000s, thus ascertaining the historical injustice. Few developing countries have even claimed 'compensation' and argued 24 "Global Greenhouse Gas Emissions Data", available at : (https://www.epa.gov/ghgemissions/globalgreenhouse-gas-emissions-data) The claim of the developing countries that curtailing their GHG emissions would negatively impact their development prospects is true and justified on that ground. It is believed that there is a strong relationship between income and per capita CO2 emissions and that the countries with high standards of living have a high carbon footprint. However, data reveal that there can be large differences in per capita emissions even among countries with similar standards of living. For instance, several countries across Europe have comparatively lower emissions than the US, Canada or Australia.

The Government of India launched National Action Plan on Climate Change (NAPCC) on 30th June, 2008 outlining eight National Missions on climate change. These include:

1.National Solar Mission
2.National Mission for Enhanced Energy Efficiency

3.National Mission on Sustainable Habitat
4.National Water Mission
5.National Mission for Sustaining the Himalayan Eco-system
6.National Mission for a Green India
7.National Mission for Sustainable Agriculture
8.National Mission on Strategic Knowledge for Climate Change

Some of the key initiatives taken by the Government of India are as follows:

7.1. Renewable Energy Targets and Initiatives:

- National Solar Mission: Promotes solar energy to reduce reliance on fossil fuels.
- Renewable Energy Capacity: India aims to achieve 50% of its energy needs from renewable sources by 2030 and has set a target of 500 GW non-fossil energy capacity by the same year.
- National Electricity Plan (NEP2023): Reflects India's ambitious renewable energy goals, aiming for a significant share of renewable energy in installed capacity.
- Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM): Supports the installation of off-grid solar pumps in rural areas and reduces reliance on grid power.

7.2. Energy Efficiency and Emission Reduction:

- National Mission for Enhanced Energy Efficiency: Focuses on reducing energy consumption in industries.
- Fuel Standards: India has adopted Bharat Stage VI (BS VI) emission standards for vehicles, equivalent to Euro VI, to reduce emissions.
- Electric Vehicles (EVs): Aims to increase the share of EVs in the automobile market, with specific targets for different vehicle categories.
- Indian Railways: Has announced plans to achieve net-zero emissions by 2030.

7.3. Addressing Climate Change Impacts:

- National Action Plan on Climate Change (NAPCC): Launched in 2008, it outlines a comprehensive strategy with eight national missions addressing various aspects of climate change.
- National Mission for Sustaining the Himalayan Ecosystem (NMSHE): Focuses on the conservation and sustainable management of the Himalayan ecosystem.
- National Mission for Sustainable Agriculture: Supports climate adaptation in agriculture through resilient crops and insurance mechanisms.
- National Mission on Strategic Knowledge for Climate Change: Aims to improve climate science, modelling, and international collaboration.
- Green India Mission: Aims to protect, restore, and enhance India's forest cover to increase carbon sequestration.

7.4. Climate Governance and Policy:

- Ministry of Environment, Forest & Climate Change (MOEF&CC): Serves as the nodal ministry for climate change matters.
- Prime Minister's Council on Climate Change: Provides guidance and oversight on climate change issues.
- National Environmental Policy 2006: Provides a framework for environmental management, including climate change considerations.
- Energy Conservation (Amendment) Bill: Sets the stage for carbon trading and incentivizes the adoption of clean technologies.

7.5. International Cooperation:

- Leadership Group for Industry Transition: Co-founded by India, it focuses on developing green hydrogen value chains.
- Global Collaboration: India actively participates in international forums and partnerships to address climate change.

8. CONFLICT OF INTEREST IN CLIMATE CHANGE RESEARCH

8.1. While climate change itself can drive conflict, there can also be conflicts of interest in how climate change is studied and addressed. For example:

(A) Financial Interests: Researchers with ties to industries that contribute to climate change (e.g., fossil fuels) may have a conflict of interest when studying or reporting on climate change impacts.

(B) Non-Financial Interests: Researchers may have other non-financial conflicts of interest, such as working with organizations that have a particular agenda related to climate change.eg. NGOs, Reginal Green Tribunals.

(C) Transparency:

It's important for researchers to disclose any potential conflicts of interest to ensure transparency and maintain public trust in climate science.

8.2. Addressing the Interconnected Challenges:

(A) Strengthening Governance:

Investing in good governance, addressing corruption, and building more resilient institutions are crucial for managing the risks associated with climate change and conflict.

(B) Promoting Sustainable Development:

Investing in sustainable development, including renewable energy, sustainable agriculture, and water management, can help reduce the impact of climate change and promote peace.

(C) Climate-Sensitive Peacebuilding:

Peacebuilding efforts should be climate-sensitive, taking into account the potential impact of climate change on conflict dynamics and incorporating climate adaptation and resilience measures.

(D) Addressing Conflicts of Interest:

Ensuring transparency and accountability in climate change research is essential to maintain public trust and ensure that research findings are used to inform effective policies.

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