

Climate change and Infectious Diseases

S Vasudevan

Editor, Kerala Medical Journal, Trivandrum*

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Many a time the news of a natural disaster like floods, cyclone and earthquake is followed by warning issued about imminent threat of outbreaks of infectious diseases and the precautions to be taken. We also hear of advisories being issued by various governments to their citizens travelling abroad on the perceived risks relating to infectious diseases that could be contracted time to time. How important are these information to safeguarding human health?

Paul Epstein, a global authority in the relationship between climate change and incidence of infectious diseases and a former associate director of the Center for Health and Global Environment, Harvard T N Chan School of Public Health argues that climate and weather are linked to each other, and to human health. He writes, “In sum, our health, the final common pathway integrating our environmental and social surroundings, is threatened in multiple ways by growing climate instability”.²

Scientists are researching how climate change may impact the spread of infectious diseases. For centuries humans have known that climatic conditions affect epidemic infections—since well before the basic notion of infectious agents was understood late in the nineteenth century. The Roman aristocracy took refuge in their hill resorts each summer to avoid malaria. South Asians learnt early that in high summer, strongly curried foods were less prone to induce diarrhoeal diseases.¹ In the southern United States one of the most severe summertime outbreaks of yellow fever (viral disease transmitted by the *Aedes aegypti* mosquito) occurred in 1878, during one of the strongest El Niño episodes on record. The economic and human cost was enormous, with an estimated death toll of around 20,000 people. In developed countries today it is well known that recurrent influenza epidemics occur in mid-winter.

Many prevalent human infections including malaria, dengue fever and cholera are climate sensitive. In some cases, such as with malaria and dengue fever,

this is in part because the causative agent for disease transmission, the mosquito cannot survive at too low temperatures. For others, climate restricts where an infection can occur by limiting the distribution of the other species needed for disease transmission.² In an article in this issue, Nidhu et al discusses the differential diagnosis to be followed in cases of fever with thrombocytopenia.⁵

Today worldwide there is an apparent increase in many infectious diseases, including some newly circulating ones like HIV/AIDS, Hantaviruses, Hepatitis C, and SARS. This reflects the combined impacts of rapid demographic, environmental, social, technological and other changes in our ways of living. Climate changes also affect infectious disease occurrence.¹

Broadly, infectious diseases may be classified into two categories based on the mode of transmission: those spread directly from person to person (through direct contact or droplet exposure) and those spread indirectly through an intervening vector organism (mosquito or tick) or a non-biological physical vehicle (soil or water).

Both the infectious agent (protozoa, bacteria, viruses, etc) and the associated vector organism (mosquitoes, ticks, sand flies, etc.) are very small and devoid of thermostatic mechanisms. Their temperature and fluid levels are therefore determined directly by the local climate. Hence, there is a limited range of climatic conditions—the climate envelope—within which each infective or vector species can survive and reproduce.

Climate is one of several important factors influencing the incidence of infectious diseases. Other important considerations include sociodemographic influences such as human migration and transportation; and drug resistance and nutrition; as well as environmental influences such as deforestation, agricultural development, water projects and urbanization

Climate variability's effect on infectious diseases is determined largely by the unique transmission cycle of

Corresponding Author:

Dr. S Vasudevan, Associate Editor, Kerala Medical Journal, Trivandrum
Phone: 9447124246, Email: periamana@gmail.com

each pathogen. Transmission cycles that require a vector or non-human host are more susceptible to external environmental influences than those diseases which include only the pathogen and human. Important environmental factors include temperature, precipitation and humidity. The role of each is different.

Directly transmitted diseases

Directly transmitted anthroponoses include diseases in which the pathogen normally is transmitted directly between two human hosts through physical contact or droplet exposure. The transmission cycle of these diseases comprises two elements: pathogen and human host. Generally, these diseases are least likely to be influenced by climatic factors since the agent spends little to no time outside the human host. These diseases are susceptible to changes in human behaviour, such as crowding and inadequate sanitation that may result from altered land-use caused by climatic changes. Examples of directly transmitted anthroponoses include measles, TB, and sexually transmitted infections such as HIV, herpes and syphilis

Directly transmitted zoonoses are similar to directly transmitted anthroponoses in that the pathogen is transmitted through physical contact or droplet exposure between reservoirs. However, these agents are spread naturally among animal reservoirs and the infection of humans is considered to be a result of an accidental human encounter. The persistence of these pathogens in nature is largely dependent on the interaction of the animal reservoir and external environment which can impact the rate of transmission, host immunity, rate of reproduction, and species death, rendering these diseases more susceptible to effects of climate variability. Hantavirus is a directly transmitted zoonosis that is naturally maintained in rodent reservoirs and can be transmitted to humans at times of increased local abundance of the reservoir. Rabies is another directly transmitted zoonosis that naturally infects small mammals, although with very little opportunity for widespread transmission, being highly pathogenic to its vertebrate host.³ Several of today's anthropogenic diseases, e.g. TB and HIV, originally emerged from animals.

Indirectly transmitted anthroponoses are a class of diseases defined by pathogen transmission between two human hosts by either a physical vehicle (soil) or a biological vector (tick). These diseases require three components for a complete transmission cycle: the pathogen, the physical vehicle or biological vector, and the human host. Most vectors require a blood

meal from the vertebrate host in order to sustain life and reproduce. Indirectly transmitted anthroponoses include malaria and dengue fever, whereby the respective malaria parasite and the dengue virus are transmitted between human hosts by mosquito vectors (vector-borne disease). Indirectly transmitted water-borne anthroponoses are susceptible to climatic factors because the pathogens exist in the external environment during part of their life cycles. Flooding may result in the contamination of water supplies or the reproduction rate of the pathogen may be influenced by ambient air temperatures.³ Cholera is an indirectly transmitted water-borne anthroponoses that is transmitted by a water vehicle: the bacteria (*Vibrio cholerae*) reside in marine ecosystems by attaching to zooplankton. Survival of these small crustaceans in turn depends on the abundance of their food supply, phytoplankton. Phytoplankton populations tend to increase (bloom) when ocean temperatures are warm. As a result of these ecological relationships, cholera outbreaks occur when ocean surface temperatures rise.

Seasonality of infectious disease

Cyclic influenza outbreaks occur in the late fall, winter and early spring in North America. This disease pattern may result from increased likelihood of transmission due to indirect social or behavioural adaptations to the cold weather such as crowding indoors. Another possibility is that it may be attributed directly to pathogen sensitivities to climatic factors such as humidity. In addition to influenza, several other infectious diseases exhibit cyclic seasonal patterns, which may be explained by climate. In diverse regions around the world, enteric diseases show evidence of significant seasonal fluctuations. In Scotland, campylobacter infections are characterized by short peaks in the spring. In Bangladesh, cholera outbreaks occur during the monsoon season. In Peru, cyclospora infections peak in the summer and subside in the winter. Similarly, some vector-borne diseases (e.g. malaria and dengue fever) also show significant seasonal patterns whereby transmission is highest in the months of heavy rainfall and humidity. Epidemics of other infections (e.g. meningococcal meningitis) tend to erupt during the hot and dry season and subside soon after the beginning of the rainy season in subSaharan Africa.

Vector borne diseases

Vectors, pathogens, and hosts each survive and reproduce within certain optimal climatic conditions and changes in these conditions can modify greatly these properties of disease transmission. The most

influential climatic factors for vector borne diseases include temperature and precipitation but sea level elevation, wind, and daylight duration are additional important considerations.

Extreme temperatures often are lethal to the survival of disease-causing pathogens but incremental changes in temperature may exert varying effects. Where a vector lives in an environment where the mean temperature approaches the limit of physiological tolerance for the pathogen, a small increase in temperature may be lethal to the pathogen. Alternatively, where a vector lives in an environment of low mean temperature, a small increase in temperature may result in increased development, incubation and replication of the pathogen. Temperature may modify the growth of disease carrying vectors by altering their biting rates, as well as affect vector population dynamics and alter the rate at which they come into contact with humans. Finally, a shift in temperature regime can alter the length of the transmission season. Disease carrying vectors may adapt to changes in temperature by changing geographical distribution. An emergence of malaria in the cooler climates of the African highlands may be a result of the mosquito vector shifting habitats to cope with increased ambient air temperatures. Another possibility is that vectors undergo an evolutionary response to adapt to increasing temperatures.

Variability in precipitation may have direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. In addition, increased precipitation may support a growth in food supplies which in turn support a greater population of vertebrate reservoirs. Unseasonable heavy rainfalls may cause flooding and decrease vector populations by eliminating larval habitats and creating unsuitable environments for vertebrate reservoirs. Alternatively, flooding may force insect or rodent vectors to seek refuge in houses and increase the likelihood of vector-human contact. Epidemics of leptospirosis, a rodent-borne disease, have been documented following severe flooding in Brazil. In the wet tropics unseasonable drought can cause rivers to slow, creating more stagnant pools that are ideal vector breeding habitats.

Humidity can greatly influence transmission of vector-borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions.

The projected rise in sea level associated with climate change is likely to decrease or eliminate breeding habitats for salt-marsh mosquitoes. Bird and mammalian hosts that occupy this ecological niche may be threatened by extinction, which would also aid the elimination of viruses endemic to this habitat.

Water-borne diseases

Human exposure to water-borne infections can occur as a result of contact with contaminated drinking water, recreational water, coastal water, or food. Exposure may be a consequence of human processes (improper disposal of sewage wastes) or weather events. Rainfall patterns can influence the transport and dissemination of infectious agents while temperature can affect their growth and survival.

Increasing temperatures may lengthen the seasonality or alter the geographical distribution of water-borne diseases. Increasing sea surface temperatures can indirectly influence the viability of enteric pathogens such as *Vibrio cholerae* by increasing their reservoir's food supply.

Heavy rains can contaminate watersheds by transporting human and animal faecal products and other wastes in the groundwater. Evidence of water contamination following heavy rains has been documented for cryptosporidium, giardia, and *E.coli*. This type of event may be increased in conditions of high soil saturation due to more efficient microbial transport. At the other extreme, water shortages in developing countries have been associated with increases in diarrhoeal disease outbreaks that are likely attributed to improper hygiene.

Future trends

Research into relationships between temporal and spatial variation of climate and the transmission of infectious diseases is summarised in three areas:

1. Evidence for associations between short-term climate variability and infectious disease occurrence in the recent past.
2. Evidence for long-term trends of climate change and infectious disease prevalence.
3. Evidence from climate and infectious disease linkages used to create predictive models for estimating the future burden of infectious disease under projected climatic conditions.⁴

END NOTE

Author Information

Dr. S Vasudevan, Associate Editor, KMJ;
Additional Professor, Department of Urology,
Medical College, Trivandrum, Kerala, India.
Phone: 9447124246
Email: periamana@gmail.com

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