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Impact of climate change on infectious diseases in India

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Abstract
The effects of climate change on human health are not well defined but it has the potential to influence the earth's biological systems. Developing nations are expected to face health effects due to climate change and global warming, including vector-borne and water-borne diseases such as malaria, cholera, and dengue. This article reviews common and prevalent infectious diseases in India, their links to climate change

Keywords: Climate change, human health, India, vector-borne disease, water-borne disease

Introduction
Infectious disease distribution involve complex social and demographic factors including human population density, behaviour, water supply, sewage and waste management systems, land use and irrigation systems, availability and use of vector control programmes, access to health care, and general environmental hygiene. Meteorological factors that influence transmission intensity of infectious diseases include temperature, humidity, and rainfall patterns. Social and demographic factors such as population growth, urbanization, immigration, changes in land use and agricultural practices, deforestation, international travel, and breakdown in public health services have been mainly responsible for the emergence and re-emergence of infectious diseases. According to the report of Intergovernmental Panel on Climate Change (2007) it was depicted that climate change may contribute to expanding risk areas for infectious diseases such as dengue and may increase the burden of diarrhoeal diseases, putting more people at risk.

Global climate change is a phenomenon that is now considered strongly associated with human activities. Atmospheric carbon dioxide levels, which have remained steady at 180-220 ppm for the past 420,000 years, are now close to 370 ppm and rising (Houghton *et al.*, 2001) [9]. Due to improvements in meteorology, we are now able to better understand long-term changes in climate. Such understanding might enable the prediction of where and when infectious disease outbreaks may occur.

Climate change and health in India
The effect of climate change on human health in India is a broad topic, covering areas from extreme weather events to shifts in vector-borne diseases. Floods create conducive environments for numerous health consequences resulting from disease transmission. For example, if floodwaters become contaminated with human or animal waste, the rate of faecal-oral disease transmission might increase, allowing diarrhoeal disease and other bacterial and viral illnesses to flourish. Faecal-oral transmission of diseases is of particular concern in regions such as South Asia because of limited access to clean water and sanitation.

In developed countries, flood control efforts, sanitation infrastructure, and surveillance activities to detect and control outbreaks minimize disease risks caused from flooding (Hales *et al.*, 2003). In developing countries, increase in diarrhoeal disease, cholera, dysentery, and typhoid is of specific concern (Morgan *et al.*, 2005). Flooding can also contribute to increased vector-and rodent-borne and other infectious diseases. For example, collections of stagnant water provide breeding grounds for mosquitoes, potentially aiding in the spread of malaria. Other studies have linked flooding in Bangladesh and parts of India with outbreaks of rotavirus and leptospirosis (Fun *et al.*, 1991; Schgal *et al.*, 2002; Karande *et al.*, 2000) [6, 10].

Rising sea-surface temperatures are expected to increase tropical cyclone intensity and the height of storm surges (Ali, 1999) [1]. Public health effects of cyclones include diseases and illnesses associated with the loss of clean water, hygiene, and sanitation, loss of shelter and belongings, population displacement, toxic exposures, and hunger and malnutrition risk due to food scarcity (Keim, 2006) [11].

Water-borne diseases

A warmer climate could cause water-borne diseases to become more frequent, including cholera and diarrhoeal diseases such as giardiasis, salmonellosis, and cryptosporidiosis (Hales *et al*., 2003). Diarrhoeal diseases are already a major cause of morbidity and mortality in South Asia, particularly among children. It is estimated that one-quarter of childhood deaths in South Asia are due to diarrhoeal diseases (Zaidi *et al.,* 2004) [17]. As rising ambient temperatures increase, bacterial survival time and proliferation and thus the incidence of diarrhoeal diseases might further increase (Checkley *et al*., 2000) [3].

Diarrhoeal diseases are largely attributable to unsafe drinking water and lack of basic sanitation; thus, reductions in the availability of freshwater are likely to increase the incidence of such diseases (Ezzati *et al.,* 2004) [5]. Rapid urbanization and industrialization, population growth, and inefficient water use are already causing water shortages in India, Pakistan, Nepal, and Bangladesh. Climate change will exacerbate the lack of available fresh water as annual mean rainfall decreases in many areas.

Cholera is a well-known water-borne diarrhoeal disease that has afflicted humankind since ancient times. Outbreaks of cholera have occurred in India, Bangladesh, and more recently, Latin America and Africa· Molecular techniques have shown that bacteria are now recognized as naturally occurring in aquatic environments. The bacterial population peaks in spring and fall in association with plankton blooms. A relationship has been observed between increase in sea-surface temperature, also associated with plankton blooms in spring and summer (Lipp *et al.,* 2002) [13].

Vector-borne and zoonotic diseases

Malaria

Malaria is one of the most serious and complex public health problems. About 400-500 million cases of malaria and more than 1 million malaria-related deaths occur globally each year (Houghton *et al*., 2001) [9]. Several factors have caused the global resurgence of malaria, including changes in temperature, rainfall, humidity, and immunity levels. Some other factors affecting malaria transmission include emergence of insecticide and drug resistance, human population growth and movement, land-use change, and deteriorating public health infrastructure.

In India malaria distribution is expected to expand to higher latitudes and altitudes. Because the relationship between climate and disease distribution is complex, in some areas increasing temperatures may restrict malaria transmission. Reductions in transmission intensity in endemic areas might lead to greater proportions of the population losing immunity, resulting in epidemics in later years (Gage *et al*., 2008) [7].

A case study done by Garg (2009) [8] reports that all of India's population is at risk for contracting malaria except for those in the areas above 1700 m above sea surface. More than 973 million persons are exposed to vector-borne malarial parasites in India, and in 1998 an estimated 577,000 disability adjusted life years (DALYs) were lost due to malaria [31].

To determine the role of climate change in malaria transmission, research efforts will be required that incorporate a disease surveillance system combining trend analyses from multiple sites to account for local factors. The first useful early warning system for epidemic malaria was implemented in India which have proven that rainfall alone accounted for about 45 per cent of the variation in malaria transmission (Kiszewski *et al.,* 2004) [12]. By the 2050s, the geographic range of malaria vectors is projected to shift away from central regions toward southwestern and northern States (Kiszewski *et al.,* 2004) [12]. The duration of the transmission window is likely to widen in northern and western States and shorten in southern States. Malaria is likely to persist in Orissa, West Bengal, and southern parts of Assam. It might shift from central India to the southwestern coastal States (Maharashtra, Kerala, and Karnataka). The northern States might also become prone. The duration of exposure is likely to widen in north and west India, and shorten in south India (Bhattachary *et al.,* 2006) [2].

Other Diseases

Climate change might affect other diseases endemic to South Asia. These include mosquito-borne diseases such as chikungunya fever and dengue, parasitic diseases such as leishmaniasis, lymphatic filariasis and onchocerciasis, and tick-borne diseases, which may exhibit changes in transmission intensity or shifts in their geographical ranges due to the impact of climate on the relevant vector populations. Climatic factors might also influence human plague, a bacterial disease carried by rodents and transmitted by fleas. Temperature and rainfall are important determinants of rodent population abundance and distribution. Combined with 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. Murine typhus, a rickettsial disease, is also transmitted by fleas and thus may exhibit similar climate sensitivity (Gage *et al.,* 2008) [7].

The activity, abundance, distribution, and ability to transmit viruses is influenced by temperature and precipitation. The first reported outbreak of chikungunya in India was in 1963 in Calcutta (now Kolkata), with transmission continuing until 1973 (Mavalankar *et al.,* 2007) [15]. The virus reemerged in 2005, and has since spread rapidly, with more than one million cases reported - despite no standardized surveillance system for the disease (Epstein, 2007; Mavalankar *et al.,* 2007) [15, 3]. Dengue has also been a significant problem, with more than 50 dengue outbreaks reported in India since 1960 (Majra and Gur, 2009) [14].

Conclusion

India, being a developing country with high population density, might experience human health effects due to climate change. These effects could be in the form of infectious diseases such as malaria, chikungunya, and water-borne illnesses. Monitoring the spread of infectious diseases will require early warning systems, which have both health and economic benefits. Health care providers will need to address the negative health outcomes associated with climate change in India at the primary level.

It is a fact that the impact of climate change in India will not be uniform. Those of low socio-economic status will likely to be the most affected. It may be expected that if India's economy continues to expand, the status of growing middle class and lower middle class would present a unique situation. The foremost effect would be seen in improved sanitation levels and living conditions, thereby increasing resilience to infectious diseases.

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