J Vector Borne Dis 49, June 2012, pp. 55–60

Review Article

Climate change and human health: Indian context

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ABSTRACT

The article reviews the issue of climate change and health in the Indian context. The importance of climate change leading to estimated loss of above 2.5 million DALYs in southeast Asia, mortality due to heat waves, and the importance of air quality related respiratory diseases, disasters due to excessive floods, malnutrition due to reduction in rice, maize and sorghum crops etc. Latest work undertaken in India, vis-a-vis current scenario and need for further work has been discussed. There is felt need of further studies on assessing the impact on dengue and chikungunya as the transmission dynamics of these diseases involve water availability, storage and life style, etc. Uncertainties and knowledge gaps identified in the studies undertaken so far have also been highlighted. As regards to vector borne diseases, there is a need to concentrate in the areas which are presently free from malaria and with use of best available tools of interventions in already disease endemic areas like northeastern states, the risk of climate change impacts can be minimized.

Key words Chikungunya; climate change; dengue; human health; Japanese encephalitis, malaria; vector-borne diseases

Climate affects water, food, air quality, diseases, physical comforts and human health. Any change in climatic conditions is likely to affect human health. Relationship between climate and health is an old one as evidenced by increase in the visit of patients to clinics after severe heat, rain and cold. Role of meteorology was also well-understood way back in 1921 when Gill[1], developed a method for early warning of malaria in Punjab. Changes in climatic conditions are usually termed as climate variability which varies from month/year-to-year. But the variability of temperature over a period of 100 years in India has been reported as 0.5°C[2] . Since 1990, there has been sharp increase in global temperatures[3] which explains the greater awareness about the potential impact of climate change on different sectors including human health. The importance of the global phenomenon was realized by the international community as far back as 1988 resulting in the establishment of the Intergovernmental Panel on Climate Change (IPCC) by the United Nations Environmental Programme and the World Meteorological Organization in Geneva which collects, analyzes and documents scientific evidences with the involvement of myriad of scientists from various disciplines looking at the impact of climate change on different sectors.

Rise in temperature, changes in rainfall and sea level rise are the major aspects that have been projected by the year 2100. The IPCC in its report of 2007[4] has projected rise of about 4°C in temperature, increase and decrease in rainfall patterns, and a rise in sea level up to 0.59 metre by the year 2100. Extremes of weather resulting in excessive heat and cold events, and disasters are also projected. Melting of glaciers are likely to result in floods, cyclones and disasters. Thus, climate change is basically climate variability which has become faster in the last two decades. After the publication of IPCC[4] , a Nongovernmental International Panel on Climate Change (NIPCC) has also been set up in USA and has produced a publication entitled 'Climate Change Reconsidered'[5] which has basically collected and compiled reports against the projected impact of climate change which raises doubts in the public health arena whether to prepare themselves for the potential threat of climate change or not.

In view of the latest developments and governments' policies, economics and political will, it is pertinent to review the latest scenario of climate change and human health in the Indian context.

Projected climate change in India

Recently, under the aegis of Indian Network of Climate Change Assessment (INCCA)[6] the report projected climate change scenario for India by the year 2030 would be in the four most vulnerable sectors, i.e. Himalayan region, northeastern, western ghats and coastal regions using A1B scenario of PRECIS model basically derived from

HadRM3. As per INCCA[6] projected rise in temperature by the year 2030 is 1.7 to 2°C. Overall rainfall shows little rise but the numbers of rainy days are likely to reduce in the western ghats, coastal areas and northeastern states. Frequency of cyclones is likely to reduce but the intensity may be severe. Rise in sea level has been projected at the rate of 1.3 ± 0.7 mm/year. There is consensus that climate change has set in, but it is not only a rise in temperature; rather decrease in temperature has also been projected.

The article reviews the potential impact of climate change on health with a view to identify the scope of formulating steps to address the negative impact in the Indian context.

Impact on human health

Possible impact of climate change on health is well-documented by the World Health Organization[7] and other international organizations like IPCC[4]. The direct impact of weather on human health is mortality due to increased temperature, disasters resulting in flood, loss of life and infrastructure due to cyclones etc, impact on water and vector-borne diseases, malnutrition and respiratory diseases[7].

The WHO estimates a global loss of 5.5 million DALYs due to climate change in 2000 (compared to baseline climate of 1961–90). The Southeast Asia Regional countries with an estimated loss of about 2.5 million DALYs would contribute nearly half (46.6%) of the total loss[7].

Impact of heat

In India, loss of life due to excessive heat occur every year. Recently, Akhtar[8] has reviewed the mortality due to heat wave in India and found that heat waves occur in the month of March to June. Maximum deaths (1658) occurred in the year 1998. Andhra Pradesh, Odisha, Punjab, Uttar Pradesh, Rajasthan, Bihar and Madhya Pradesh were the most affected states. With projected rise in temperatures, mortality is expected to rise due to heat waves. The National Physical Laboratory, New Delhi is working on assessment of heat stress on human health in view of climate change and using PRECIS model for A1B scenario and showed high occurrence of maximum temperature for three consecutive days in the range of 45–50°C in April to June months in the years of 2030, 2050, and 2080 in some districts of Andhra Pradesh, Bihar, Gujarat, Odisha, Rajasthan, Uttar Pradesh, and West Bengal[9].

Increased temperatures are also likely to cause increase in eye diseases like cataract, dry eyes, pterygium, and vernal keratoconjunctivitis and skin diseases. The impact of global warming and ultra-violet radiation on eye diseases is being studied in the National Capital Region of Delhi and Guwahati (R. Tandon, AIIMS, New Delhi, India personal communication).

Heat wave mortality and morbidity in 2003 and 2006 in Europe and USA respectively[10,11] at a maximum temperature of 35°C in seven French cities was found exceptional leading to mortality, while in India even at higher temperatures people survive in the eastern part of the country. This indicates that the local adaptive capacity of people plays a key role. Thus, there is large scope of studying the vulnerable region, month, cut offs of temperature, age group and malnutrition status of victims of heat wave so as to provide health advice to the people. The only expected positive impact of rise in temperature on health is reduction in mortality due to cold wave in some parts of northern India.

Air quality-respiratory diseases

Warmer air temperatures can influence the concentration of regional air pollutants and aeroallergens. Allergenic pollens grow more profusely in a warmer climate leading to respiratory disorders such as asthma, emphysema and chronic bronchitis, and allergy problems[12,13]. Vehicular pollution, particularly in metropolitan cities experience heavy smog and haze resulting in asthmatic attacks. When combined with smog and other atmospheric pollutants, illness from allergic respiratory diseases, particularly asthma, could increase. Changes in the climate also affect diseases like chronic obstructive pulmonary disease, pneumothorax, and respiratory infections in children[14]. There are also indications of relationship between air pollution and tuberculosis. Further, there is some evidence that dust storm in deserts as well as high altitude areas can lead to respiratory problems[15]. There is ample scope of establishing a relationship between climate change and exacerbation in respiratory diseases in India.

The quality of air is likely to decrease as surface ozone concentrations begin to rise with increasing temperatures. This will lead to an increasing incidence of asthma and other cardiovascular and respiratory diseases[16]. This issue is being addressed by the Govt. of India by introducing compressed natural gas (CNG) for transport and replacement of wood fire for cooking by the liquid petroleum gas (LPG) in villages[17]. It is an excellent example of co-benefits of other sectors to human health.

Disasters

Excessive floods, cyclones, storms and earthquakes usually cause loss of life, infrastructure and human resources. As per projections of extreme events due to cli-

mate change, loss of life and mental stress are expected in vulnerable people. Coastal areas of India, particularly the east coast and Andaman & Nicobar Islands are vulnerable to cyclones and tsunamis. Lessons learnt from the past would serve as guiding principle for formulating preventive measures and combating tools. National Institute of Disaster Management, set up by the Government of India is making headway in imparting training to different sectors and mapping the disaster prone areas in India which should serve as a baseline for development of preparedness plans to meet adverse impacts (http://nidm.gov.in/default.asp). Documentation of lessons learnt in combating disasters should be encouraged so that preventive/adaptation measures can be advocated.

Diarrhoeal diseases

Excessive floods contaminate drinking water creating conditions for transmission of diarrheal diseases like cholera. In India, the figures for estimated disability adjusted life years (DALY) lost due to diarrhoeal diseases were 23,801,447 in 2006 and by 2016, 21,486,636 DALYs are projected[18]. The Energy and Resources Institute, New Delhi (http://www.teriin.org/) and National Institute of Cholera and Enteric Diseases (NICED), Kolkata undertook a research project to examine the potential relationship between climate change and diarrhoeal diseases, assess the vulnerability and adaptability and evaluate the economic impact[19]. Recently, distribution of cholera has been reported in 21 states of India (out of 35) and concluded that reporting is incomplete. Therefore, there is a need to establish reliable surveillance systems and generate evidence showing the link between diarrhoeal diseases and climate change[20].

Water scarcity and malnutrition

Water is fundamental for life. Scarcity of water or excess water due to floods, cyclones are likely to affect human health. Scarcity of availability of water for crops and high temperatures will affect agriculture resulting in less production. As per World Bank, India ranks at number 2 after Bangladesh where about 47% of children exhibit a degree of malnutrition[21]. Diseases like diarrhoea, malaria, typhoid and pneumonia further add misery to the problem. Recent work on the impact of climate change on agriculture in India has been assessed for four sectors under the aegis of the INCCA[6]. The projections indicate reduction in rice, maize, sorghum from 4 to 50% in different sectors. The apple production is also projected to be reduced. Coconut yield may increase by 30% in coastal areas while there is projection of reduction in Tamil Nadu, Maharashtra and parts of Karnataka. Livestock produce like milk may also reduce[22]. The reduction in agricultural produce is bound to have a negative impact on human health leading to malnutrition, if not addressed in time.

Vector-borne diseases

Spatial and temporal distribution of vector-borne diseases like malaria, dengue and chikungunya are likely to be affected the most as the mosquitoes which transmit the diseases are cold blooded . Their life cycle and development of pathogen in their body are likely to be affected at varying temperature and relative humidity. Studies undertaken in India with A2 scenario on malaria reveal that the transmission window in Punjab, Haryana, Jammu & Kashmir and northeastern states are likely to extend temporally by 2–3 months and in Odisha, Andhra Pradesh and Tamil Nadu there may be reduction in transmission windows. The link between re-emergence of kala-azar in northern parts of India and reappearance of chikungunya mainly in southern states of India appears to be due to changing climatic conditions which needs to be elucidated. The issue of VBD and climate change in India has been dealt[23].

Dengue

Major issue of concern is urbanization in the context of VBD, particularly dengue and chikungunya. Impact of climate change on dengue also reveals increase in transmission with 2°C rise in temperature in northern India as reviewed in 2010[23]. The thresholds of temperature and relative humidity for indigenous transmission of dengue need to be redefined. Risk factors in terms of water availability, storage practices and life style also need to determined. As adaptation measures, early warning system for preventing outbreaks is need of the hour. In a preliminary study using A1B scenario of PRECIS model, transmission windows for dengue transmission (20–32°C temperature and >55% RH) were projected by the year 2030 which show increase in transmission months open for dengue transmission in northern areas and reduction in western part of southern India[9]. However, it seems inconclusive in view of water storage practices, intra-domestic breeding of *Aedes* vector and socioeconomic conditions of inhabitants.

Japanese encephalitis

Incidence of JE in India has increased in eastern Uttar Pradesh in the last five years and the epidemiology has also posed problems as cases of Acute Encephalitis Syndrome also occur in JE endemic areas[24] and personal communication with M.M. Gore, NIV Unit, Gorakhpur, India. The knowledge about lower and upper thresholds of temperature, rainfall and RH required for JE endemicity

is still lacking. Inroad of JE into Delhi is also a matter of investigation to define the ecological/climatic and sociological changes which led to introduction of JE in Delhi. Modern approach using Remote Sensing and Geographical Information System is required to map the ecological and environmental risk.

Recently, a publication[5] quotes Gage *et al*[25] that climate change could increase outbreaks and the spread of some vector-borne diseases while having quite the opposite effect on other vector-borne diseases. This issue is debatable and need for holistic view of ecology and epidemiology of vector-borne disease like malaria has been emphasized[26]. Even Hay *et al*[27] concluded that the reason of increased incidence of malaria in African highlands was due to biological factors (drug resistance in malaria parasite). When the matter of malaria in African highlands was revisited it provided evidence that increased malaria was due to increased temperature[28]. Again, a publication reported that in malaria in spite of threat of climate change there has been global recession[29]. In 2011, again it was emphasized that "climate should not be dismissed as potential driver of observed increase in malaria[30] . It is true that the climate change impacts are not projected uniformly and spatially and for all VBDs and necessitates insight of disease epidemiology, ongoing interventions and socioeconomic change for determining exclusive burden due to climate change.

Impact of sea level rise

Inundation of sea coasts as per projections is likely to affect poor population in terms of mortality, stress and loss of infrastructure. Vector-borne diseases are not likely to be affected as *Anopheles sundaicus* (Diptera: Culicidae), a brackish water breeder mosquito vector of malaria is confined to Andaman & Nicobar Islands only and there is no chance of entering into the mainland.

Current evidence

Reporting of malaria and dengue in Nepal and Bhutan, chikungunya in India since 2005, and occurrence of kala-azar in Himachal Pradesh and reappearance in Asom are some of the examples which can be linked to climate change but need verification.

It is true that intervention measures have remarkable impact on disease incidence than other factors like insecticide resistance in mosquito vectors and drug resistance in parasites. The projected impacts of climate change are likely to introduce a particular VBD in an area where temperature is a limiting factor, while there is increased intensity of transmission in areas already experiencing transmission at moderate level. Reduction is also projected in areas already experiencing very high temperatures. As regards dengue, almost the whole of India is suitable from the climatic conditions point of view but central and northeastern states are not endemic. Life style and water supply system are the major determinants of indigenous transmission of dengue. The example of USA not having dengue problem can be cited basically due to better life style which does not support breeding and man vector contact.

As regards visceral leishmaniasis (VL), elimination is targeted by the year 2015, therefore, the best available tools are in practice to achieve the goal. However, it seems difficult due to covert infection and unsatisfactory impact of indoor residual spraying.

The vectors of filariasis are widely distributed and may be less affected by climate change as compared to *Culex vishnui* (Diptera: Culicidae) group of vectors of Japanese encephalitis. However, there is scanty information about these diseases.

With regard to the future scenario of VBD in India from the viewpoint of climate change impacts, there is a strong National Vector Borne Disease Control Programme (NVBDCP). In the field of malaria, under Global fund grant, hard core malarious states like Odisha and northeastern states are covered with Artemisinin-based combination therapy for the treatment of drug resistant malaria patients and long-lasting nets for personal protection, and the results are encouraging. No major outbreaks since 2006 have been witnessed except in a localized area at construction sites in Mumbai during 2010-11[31]. The recent projections made for the year 2030 on transmission intensity of malaria show the possibility of a few new foci in Himalayan region[32], increase in intensity of transmission in northeastern states while reduction in a few east coastal areas has also been projected.

Uncertainties and knowledge and research gaps in impact assessment on malaria and dengue

Uncertainties: Analyses of impact assessments have been done using mean temperature only, therefore, studies are warranted using diurnal temperature. Mitigation measures can change the scenarios and the projections made for transmission window may be affected drastically by intervention measures, ecological changes and socioeconomics of the communities.

Knowledge gaps: In some geographic areas, transmission of malaria occurs at very high temperatures beyond 40°C which suggests the presence of micro-niche, that needs to be studied in detail, particularly in areas like Gujarat and Rajasthan. Based on the outputs of open months for ma-

laria transmission, validation is needed at the district level to determine cut-off limits of transmission for temperature, RH and rainfall. The study should be expanded to other vector-borne diseases other than malaria and dengue in India. The outcome of projections is based on only climatic parameters alone, which if integrated with intervention measures, socio-economics and immunity of the population would provide a holistic projection. There is need for strengthening measures like early warning of outbreaks using erstwhile rainfall and newly analysed satellite derived vegetation index[33,34]

Vulnerability assessment

The vulnerability-resilience indicator prototype (VRIP) model has been applied to the 26 Indian states on the basis of following indicators such as: economic capacity, human and civic resources, environment capacity, settlement/infrastructure sensitivity, food security, ecosystem sensitivity, human health sensitivity and water resource sensitivity and found that only 3 states are most vulnerable, 23 states less vulnerable, and 9 states showing resilience[2]. With improved surveillance and introduction of best available tools for malaria control (providing diagnostic kits in difficult areas, Artemisinin-based combination therapy for *Plasmodium falciparum* in the whole country and long lasting nets for personal protection and economic development), the vulnerability assessments may not hold true for a longer time.

CONCLUSION

Climate change has set in and will alter spatial and temporal distribution of vector-borne diseases, exacerbation in heat related mortality, air pollution related respiratory diseases and water borne diseases, if current scenario continues. In tropical countries like India, most of the identified adverse health effects due to climate change are already experienced. The need of the hour is to undertake situation analysis for reasons of persistent disease burden and for identifying the operational gaps. In order to develop preparedness plans for hitherto free and already disease endemic areas, impact assessment at district level keeping in view the ecology, life style and disease epidemiology, additional population at risk due to climate change alone, strengths and weaknesses of health system , health education to vulnerable groups and institution of best available tools of intervention are needed. Local practices being practiced by the communities to face challenges like floods, heat strokes, and protection from mosquito bites should be documented and encouraged as adaptation measures. Owing to multi-factorial nature of transmission dynamics of vector-borne diseases, intervention measures can result in a dramatic change in reduction of disease burden and thus nullify the potential threat due to climate change. The major threat is to the countries which are presently non-endemic for vector-borne diseases or other problems like heat wave mortality or disasters etc, as they do not have experience of tackling the threat as compared to those who are already having infrastructure to control the diseases. Economics would play a major role in combating the potential threat. Countries with good GDP would be able to introduce the best available tools of intervention and can fill up the lacunae in health system.

Health issues identified by the Prime Minister's National Action Plan on Climate Change in India (source: http://www.pmindia.nic.in):

- Provision of enhanced public health care services
- Assessment of increased burden of disease due to climate change
- Providing high-resolution weather and climate data to study the regional pattern of diseases
- Development of a high-resolution health impact model at the state level
- GIS mapping of access routes to health facilities in areas prone to climatic extremes
- Prioritization of geographic areas based on epidemiological data and the extent of vulnerability to adverse impacts of climate change
- Ecological study of air pollutants and pollen (as the triggers of asthma and respiratory diseases) and how they are affected by climate change
- Studies on the response of disease vectors to climate change
- Enhanced provision of primary, secondary and tertiary health care facilities and implementation of public health measures, including vector control, sanitation, and clean drinking water supply.

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Received: 15 May 2012 *Accepted in revised form:* 15 June 2012