CLIMATE CHANGE AND RISK OF LEISHMANIASIS IN INDIA

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ABSTRACT

Climate and other environmental changes have the potential to expand the geographic range of the sand fly vectors and the areas in the world where leishmaniasis is found. Kala-azar or Visceral Leishmaniasis (VL) is a parasitic disease caused by Leishmania donovani. On the Indian subcontinent, it is transmitted by the sand fly, Phlebotomus argentipes. Kala-azar is found in about 88 tropical and sub-tropical countries with approximately 350 million people living in affected areas and at risk of infection. About 5,00,000 cases occur annually. More than 90% of the world’s VL cases are in India, Bangladesh, Nepal, Sudan, and Brazil, affecting largely the socially marginalized and the poorest communities. In the South-East Asian Region, kala-azar occurs in India, Bangladesh, and Nepal with a small focus reported in Bhutan. In this region about 200 million people are “at risk”. 52 districts in India, 12 in Nepal, and 45 in Bangladesh are endemic. Most of the SEAR countries are vulnerable to the consequences of climate change. The ultimate effects of climate change are increased flooding, the breakdown of sanitation systems increased salinity, more vector growth, and more water- and food-borne diseases, which ultimately impact human health. Environmental changes often modify the transmission patterns of vector-borne diseases. Increases in temperature due to climate change provide a better breeding environment for vectors, including the sand fly, in places where temperatures were previously below optimum and so, a higher rate of human VL infection may result. Further research in this area is needed. The geographical distribution of leishmaniasis includes 88 countries and almost 350 million people live in these areas where the disease has been considered as one of the most severe problems of public health. According to the findings of “impact of climate variability and change on leishmaniasis”, the distribution of Leishmaniasis is affected by the global climatic changes. This preliminary data show how climatic changes influence the occurrence of leishmaniasis in India and contributes to the growing body of evidence that shows that the incidence of vector-borne diseases is associated with annual changes in weather conditions. These changes of contact in turn are modulated by both direct effects on the biology and ecology of the organisms involved, as by perceptions and changes in the behavior of the human communities at risk. Therefore, from the perspective of public health and state policy and taking into account the current nonlinear increased velocity of climate change, we concluded that discussing the uncertainties of large-scale models will have lower impact than to develop-validate mitigation strategies to be operative at local level and compatibles with sustainable development, conservation, biodiversity and respect for cultural diversity.

INTRODUCTION

Leishmaniasis is a vector-borne disease transmitted by numerous sand fly species caused by obligate intracellular parasitic protozoa of the genus Leishmania. Climate change is increasingly being implicated in species’ range shifts throughout the world, including those of important vector and reservoir species for infectious diseases. The Indian subcontinent is prone to the occurrences of chronic Visceral Leishmaniasis (VL) or Kala-azar and geographical distribution of disease is endemic in the states of Bihar, West Bengal, Uttar Pradesh, Jharkhand, Delhi, Gujarat, Madhya Pradesh and Kerala states. The world distribution of Kala-azar chronic cases occurring in the countries, such as, Brazil, India, Nepal, Bangladesh and Sudan, and the 90% of the disease has been mainly affecting the children of below 9-15 years of age and it has been causing 50% of the cases turning to death incidents occurring annually in India (Sharma, et. al., 2007). The northeastern regions of India, southern region of Nepal and eastern and central division of Bangladesh in South-East Asia are prone to endemic regions of Visceral Leishmaniasis transmission. The reports of Kala-azar cases occurring in
Bihar state in India, which is 40% to 50%, of the world cases and is severely affected state which accounts to 90% of the total recorded cases in India. Approximately 1.5 Lakhs Cutaneous Leishmaniasis and 5 Lakhs Visceral Leishmaniasis occur over the world yearly. After malaria, this disease is considered as the second biggest health problems in the world (Desjeux, 2001). Leishmaniasis usually is more common in rural than in urban areas, but it is found in the outskirts of some cities. Leishmaniasis is found in people in focal areas of approximately 90 countries in the tropics, subtropics and southern Europe. It is endemic in warmer parts of the world covering almost 88 countries (16 developed and 72 developing countries) around the globe with a total of 350 million people at risk and 12 million cases with infection. Out of 5 lak cases of VL, more than 90 percent are reported from India, Bangladesh, southern Sudan, Nepal and northeast Brazil. Sand fly (Phlebotomus argentipes) that lives in warmer places (crevices, tree holes, dung and domestic wastes) where humidity and temperature both are present at regular intervals in a day (humidity during night and temperature during the day). These conditions are essential / necessary for the survival of the vector, parasite development and also for their distribution. But, now a days, due to global climate changes and temperature increases, which support the high degree of sand fly growth, the transmission of disease has increased manifolds. In general, sand flies are found in dry areas, then, when climate shift tends to dryer environmental conditions, vector populations could increase, and therefore, leishmaniasis transmission may be higher. Our study attempts to evaluate the impact of climate variability and its potential influence in the number of leishmaniasis cases in Indian subcontinent. The proliferations of vector-borne diseases are predicted to increase in a changing climate and Leishmaniasis, as a vector-borne disease is re-emerging in several regions of the world.

Old World Leishmaniasis

A study carried out in India, analyzed in ‘Silicon Graphic Image Processing System’, using ERDAS software, some data obtained from a remote sensing satellite (Sudhakar et al., 2006), the GIS functions were applied to quantify the remotely sensed landscape proportions of 5 km² buffer in determined places of high occurrence of sand flies in endemic and non endemic areas. Through the combination of Remote Sensing (RS) and Geographical Information System (GIS) they developed landscape predictors of sand fly abundance, an indicator of human vector contact and as a measure of risk prone areas. It was indicated, that the environmental factors such as type and density of settlements, proximity to these with that of water bodies, marshy areas with succulent weed cover and also crops of high succulence in nature like sugarcane, bananas coupled with local prevailing conditions had definitely interactive influencing effect of vector density and also incidents of vector borne diseases. Satellite imagery complemented with a GIS database, estimated parameters such as altitude, temperature, humidity, rainfall and the ‘Normalized Difference Vegetation Index’ (NDVI) for correlation with the distribution of Kala-azar in India (Bhunia, et. al., 2010). They observed that the highest prevalence was below 150 m of altitude with very few cases located above the 300 m level and a low NDVI value ranges correlated with a high occurrence of the disease. They also showed, that most of the cases occurred in non-vegetative areas or low density vegetation zones highlighting that the low density vegetation zones were significant for the P. argentipes vector distribution in the disturbed areas. The distribution of phlebotomine sandflies varies highly within its range, depending on local environmental factors, such as precipitation and temperature, physical factors, such as geographical barriers, habitat availability and biotic factors such as the distribution and abundance of vertebrate hosts (Singh & Phillips-Singh, 2009).

Housing Conditions and Kala-azar

In this study, it was observed that the risk of kala-azar was higher among cases with a history of kala-azar among the family members in the past year compared with those cases with no history of kala-azar among the family members. The presence of kala-azar cases in the family might aid the transmission of this disease in the presence of sand fly vectors and other conditions favorable for completion of transmission cycle within the house.

The use of mud for wall construction or for plastering walls was found to be significantly associated with kala-azar, a finding previously reported in other studies (Thakur, 2000 & Dhiman & Sen, 1991).

Climate Change in India

India is considered a country vulnerable to the adverse impacts of global climatic change (Srinivas, 2017). The main reasons raised are inadequate adaptive capacity for high water stress, socio-ecological and economic problems linked to food and water security and uncontrolled migration. In rural areas of India, houses are usually surrounded by moderate-to-high density vegetation such as seasonal crops, bananas, bamboo trees, small creepers, climbers and herbs. The presence of vegetation was significantly associated with kala-azar in univariate analysis, but not in multivariate analysis. The presence of vegetation as a risk factor of kala-azar has also been previously reported (Dhiman & Sen, 1991). Changes in temperature, rainfall and humidity can have strong effects on vectors and reservoir hosts by altering their distribution and influencing their survival and population sizes; small fluctuations in temperature can have a profound effect on the developmental cycle of Leishmania promastigotes in sandflies, allowing transmission of the parasite in areas not previously endemic for the disease. Drought, famine and flood can lead to massive displacement and migration of people to areas with transmission of Leishmania and poor nutrition could compromise their immunity (Hlavacova et al., 2013 & WHO, 2019). If the transmission of Leishmania by sand flies is sensitive to temperature change, many other factors may also play a role in the modulation of its spread. Of these, some are linked to the socio-economic determinants, which also requires the collection of appropriate climatic (e.g., temperature and precipitation) and non-climatic data (e.g., ozone). Surveillance of extreme weather conditions and risk indicators such as mosquito abundance or pathogen load is also necessary (Sharma & Singh, 2008, Bush et al., 2011 & Hirve et al., 2017), the parasite (virulence and drug resistance) (Singh et al., 2016) and the host (immune, nutritional or genetic status of the host) (Sakthianandeswaren et al., 2009) relationship.

Most transmission of Leishmania is by the bite of permissive sandflies and so climate change might affect leishmaniasis
distribution directly by the effect of temperature on parasite development in female sandflies (Bates, 2007) or indirectly by the effect of environmental variations on the range and seasonal abundances of the vector species. Female sandflies seek sheltered resting sites for blood meal digestion and in southern Europe the temperatures of these micro-habitats are buffered but vary significantly with the external air temperatures (Ready, 2008).

Most transmission of Leishmania species is by the bite of permisive female sandfly species (i.e. those permitting the development of infective parasites) and so climate change will affect the distribution of leishmaniasis in three ways:

1. directly, by the effect of temperature on parasite development and vector competence
2. indirectly, by the effect of temperature and other environmental variables on the range and abundance of the sandfly species that act as vectors
3. indirectly, through socio-economic changes that affect the amount of human contact with the transmission cycles.

Effect of Temperature and Humidity on the Survival of sand fly

Temperature and humidity play an important role in survival of sand fly, development and its activity. Sand fly (Phlebotomus argentipes) can survive cold temperatures in diapause (overwintering), which is initiated by a combination of low temperature and reduced daylight and can last for 4 to 8 months depending on the location. Temperature also affects the activity and growth of the parasite. The worldwide distribution of sand flies is considered to be confined to areas that have at least one month with a mean temperature of 20°C (Singh, 1999). The impact of temperature on sandfly populations is rapid and the distribution vegetation condition and synoptic temperature to an overall accuracy of more than 80% (Thanyapraneedkul et al., 2009).

Human Activity and Leishmania Transmission

Transmission of leishmaniasis is influenced by human affected environmental changes (Walsh, 1993), such as deforestation for socio-economic reasons increases the inflow of Leishmania transmitting vectors and possible reservoir hosts from forest-rural areas into semi-urban and urban human settlements (Patz et al., 2000, Dawit & Shishay, 2014 & Walsh et al., 1993). Deforestation and urbanisation are known to affect leishmaniasis worldwide (Desjeux, 2001) because of the associations of many vectors and reservoirs with natural or rural areas. A wide range of activities have resulted due to deforestation. Deforestation, an ongoing problem in the developing world creates ideal conditions for vectors to breed and spread infectious diseases. These include colonization and settlement, trans-migrant programmes, logging, agricultural activities to provide for cash crops, mining, hydropower development and fuel wood collection. Each activity influences the prevalence, incidence and distribution of the vector-borne disease.

The main environmental risk factors, namely, urbanisation, with the spread of suburbs nearer to gerbil colonies and irrigation schemes expanding the reservoirs’ ranges cross-border migration is also a risk factor for the emergence of Kala-azar in India, Bangladesh and Nepal, where low socio-economic status is the principal risk factor for the disease. Extreme poverty is associated with disease-enhancing malnutrition and greater contact with the vector Phlebotomus (Euphlebotomus) argentipes, which is abundant in cowsheds and in locations with a high subsoil water level, but no flooding (Desjeux, 2001). In the Indian subcontinent, cross-border migration is also an important risk factor for AVL dissemination. Most of the leishmaniasases are rural and many are zoonoses and so there has been much descriptive ecology of their ‘landscape epidemiologies’ and recognition of qualitative risk factors (Desjeux, 2001). For example, there is a permanent movement of population between India (Bihar and Uttar Pradesh States) and Nepal (Morang District in Terai) and vice versa as AVL patients frequently cross the border looking for available drugs (Desjeux, 2001).

VL status in North India confirms that longevity and survival of vector populations of Kala-azar is significantly determined by the major risk factors, such as geographically controlled factors- the climate, environmental conditions viz. vegetation, temperature, humidity, rain, wind speed, natural calamities, socio-economic conditions, poverty, livelihood and deforestation (due to urbanization). Some of the important associated risk factors need to be taken care of, such as poor sewerage, crowded housing, non-use of bed-nets, lack of cleanliness due to illiteracy, presence of granaries inside the houses, sleeping near domestic animals, improper drainage system, human behavior, vegetation around the house, crop and soil type (water retentive), stray dogs (reservoirs of the parasite) in the locality and human settlements close to the forests, all are the cause of sand fly propagation and the parasite transmission in Bihar, Jharkhand and West Bengal (Singh & Philips-Singh, 2019). Human infection with Leishmania parasites is dependent on the ecological relation between human activity and the reservoir systems. Any change in the environmental factors is likely to lead to a change in the distribution of the parasite (Ashford, 2000).

RESULTS AND DISCUSSION

Leishmaniasis is still an important public health problem due to not only environmental risk factors such as massive deforestation, urbanisation and migrations, new irrigation schemes, but also to individual risk factors like HIV, malnutrition, genetic, etc.. Leishmaniasis is part of those diseases which still requires improved control tools (Desjeux, 2004). The modification of the environment is also closely associated with both cultural issues as climate change, generating a cascade of events that can start with deforestation, followed by changes in land use and human settlements, habitat fragmentation, border effect, increased abundance or contact with synanthropic reservoirs, clustered food sources for vectors (domestic animals), pressure for adaptation of vectors to modified environments and anthropophily, irrigation and water storage systems and optimization of vector and reservoirs’ breeding conditions (Ouanaıì, et. al., 2011). By convention, the habitat of P. argentipes is assumed to be restricted to areas in and around peoples’ homes (Malaviya et al., 2014). Indoor residual spraying is therefore assumed to be an effective vector control measure and is a key component of the visceral leishmaniasis elimination strategy. Public health measures such as case detection and treatment, the control of sand flies, the
conjunction elimination of infected stray dogs and health education can be effective in controlling the disease (Singh & Phillips-Singh, 2010). As a byproduct of massive chlofenotane (commonly known as DDT in rural areas) spraying in the malaria eradication campaigns of the 1950s and 1960s, visceral leishmaniasis disappeared from the Indian subcontinent for over a decade, until resistance to chlofenotane emerged and became widespread (Coleman et. al., 2014 & Kumar et. al., 2015). The world’s climate seems to be changing at an unprecedented rate (Sutherst, 2004, Rodriguez-Morales, 2005, Patz et. al., 2000 & McMichael et. al., 2003). In this scale the variables associated with the climate, as the low temperatures, mainly the winter in the latitudes with distinct seasons, was suggested as a period with no adult activity from the vectors of leishmaniases. However, competent vectors have been captured during temperate winter nights in microhabitats protected from sudden climate changes as the primary forest remnant patches (Salomón et. al., 2001) or habitats that moderate these changes as patches of secondary vegetation (Salomón et. al., 2008).

Shifts in the distribution and behavior of insect vectors and bird species indicate that biological systems are already adapting to ecological variations. It is well established that climate is an important determinant of the distribution of vectors and pathogens (Sutherst 2004, Rodriguez-Morales 2005, Patz et. al., 2000 & McMichael et. al., 2003) such as those of malaria, (Rogers et. al., 2002, Zhou et. al., 2005, Benítez et. al., 2004), Dengue (Cazelles et. al., 2005) and recently, leishmaniasis (Cross & Hyams, 1996, Cross et. al., 1996, Kuhn 1999, Kovats et. al., 2001, Afonso et. al., 2005 & Cabaniel et. al., 2005). Given the substantial burden of disease associated to vector-borne diseases in developing tropical countries, it is of utmost relevance to incorporate climate changes into public health thinking (Rodriguez-Morales 2005 & Kovats et. al., 2001). Although our study may have some limitations such as a lack of incorporation of other meteorological factors into the analysis, we strongly believe that our findings are relevant from a public health perspective to better understand the eco-epidemiology of this and other tropical infections (Rodriguez-Morales, 2005 & Kovats et. al., 2001). However, further research is needed in this region and in the other endemic areas to develop monitoring systems that will assist in predicting the impact of climate changes in the incidence of leishmaniasis and other vector-borne tropical diseases in endemic areas with various sand fly species and Leishmania species (Sutherst 2004, Rodriguez-Morales 2005 & Cross et. al., 1996). Many P. argentipes sandflies in outdoor locations and analysis of sandfly-acquired blood revealed that up to 90% of blood fed sandflies captured from palm tree canopies had fed on people (Poche et. al., 2011).

Phlebotomus argentipes sand flies are commonly found in cracks and crevices of mud walls, mud- plastered walls or unplastered brick walls in rural areas of Bihar. These endophagic sand flies usually breed inside cowsheds and human dwellings, especially inside cracks and crevices of walls where optimum temperature and humidity are available (Hati, 1983). Mud walls can retain moisture for many months after the rainy season, which further increases favorable conditions for sand fly breeding and resting (Napier, 1926). Filling of cracks and crevices in walls with a mixture of lime and mud has been advocated as an ecologic approach for the control of P. argentipes inside houses (Kumar et. al., 1995).

The geographical distribution of Visceral Leishmaniasis otherwise known as Kala-azar in India, has been directly controlled by the specific crop vegetation types, increasing trend of irrigation facilities to the agricultural practices of cultivation areas, amount of rainfall, relative humidity, areas with edible shrubs and plants, alluvial soil type, is dark coloured and alkaline in nature with (pH 7.2-8.5), calcareous with chief inorganic constituents of silicon, iron and aluminium (Palaniyandi et. al., 2014).

There is a permanent worldwide risk of a resurgence of leishmaniasis not only because of the appearance of new risk factors but also because of a sudden and significant increase in previously identified ones. Permanent awareness based on continuous health education and strict surveillance including early warning systems are crucial to reduce this risk. Each environmental change, whether occurring as a natural phenomenon or through human intervention changes the ecological balance and context within which disease hosts or vectors and parasites breed, develop, and transmit disease. Each species occupies a particular ecological niche and vector species sub-populations are distinct behaviorally and genetically as they adapt to man-made environments. Most zoonotic parasites display three distinct life cycles: sylvatic, zoonotic and anthroponotic. In adapting to changed environmental conditions, including reduced non-human population and increased human population, some vectors display conversion from a primarily zoophilic to primarily anthropophilic orientation. Deforestation and ensuing changes in land use, human settlement, commercial development, road construction, water control systems (dams, canals, irrigation systems, reservoirs), and climate, singly and in combination have been accompanied by global increases in morbidity and mortality from emergent parasitic disease. The replacement of forests with crop farming, ranching and raising small animals can create supportive habitats for parasites and their host vectors. When the land use of deforested areas changes, the pattern of human settlement is altered and habitat fragmentation may provide opportunities for exchange and transmission of parasites to the heretofore uninfected humans. Construction of water control projects can lead to shifts in such vector populations like snails and mosquitoes and their parasites. Construction of roads in previously inaccessible forested areas can lead to erosion and stagnant ponds by blocking the flow of streams when the water rises during the rainy season. The combined effects of environmentally detrimental changes in local land use and alterations in global climate disrupt the natural ecosystem and can increase the risk of transmission of parasitic diseases to the human population. In addition to these bio-ecological data, it is also important to assess the economic and socio-cultural risks, prioritized by experts and to associate these with scenarios that use various climatic parameters, including land use/cover, poverty, urbanization, migration, and demography trends. Therefore, effort should be made in selecting adequate indicators in terms of time and space, to gather data with appropriate quality in terms of resolution, units, sensitivity, specificity and accuracy. This will help define and establish an effective prevention strategy consistent with events previously defined (risk maps, monitoring and health rules) and categorized by the region and period at risk. Finally, it is necessary to develop and adopt an early warning system based on the integration of...
statistical/spatial prediction models using monthly or yearly climatic and disease outbreak data, density or activity for both vectors and reservoirs and an appropriate field-based surveillance response, which will enhance surveillance. Environmental factors, whether biotic or abiotic, have revealed a real impact on the distribution of these diseases. In conclusion, innovative, multidisciplinary investigations using environmental epidemiologic methods to elucidate health risks posed by climate variability and subsequent climate change in regions such as India are possible. However, such work will require expanded partnerships among researchers, governments and communities to develop a co-benefit strategy that addresses public health challenges and risks associated with climate change. Adoption and implementation of these research initiatives will provide the necessary tools and infrastructure to pose interesting scientific questions and design effective solutions to the complex issues imposed by climate change.

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References