The Impact of Climate Change on Emergence and Re-emergence of Vector-borne Human Diseases

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Abstract

Climate change is happening with greater speed, and intensity in the world, than it was initially predicted. Climate change refers to any significant changes in climate through, temperature, precipitation, wind, etc., for an extended period, as a result of the natural processes, such as sun's intensity, ocean circulation, and human activities causing changes in the atmosphere's composition through burning fossil fuels and deforestation. Climate change has a significant impact on human and animal health with regard to certain infectious diseases mainly transmitted through arthropod vectors. Climate change may affect disease by increasing the transmission cycles of vectors, and some regions, it may result in establishment of new diseases. The basic transmission cycle involves arthropod-animal host amplification, with humans acting as a dead-end host. Nearly half of the world's population is infected by vector borne diseases, resulting in high mortality and morbidity. The important vector borne diseases affected by climate change include Chickengunya fever, dengue fever, dirofilariasis, Japanese encephalitis, leishmaniasis, malaria, plague, Rift Valley fever, tickborne diseases, trypanosomiasis, and West Nile fever, Over the next decades, it is predicted that billions of people in the world, particularly those in developing countries, will face the shortage of water and food, and greater risks to health, and life due to the climate change. Hence, continued interdisciplinary research is needed to understand the association between climate, weather, and infectious diseases. Predictive modeling should be developed to forecast the impact of climate change on the emergence of diseases, which affect the health of humans and animals. Additional studies should be conducted on disease dynamics, and how they may adapt to a changing climate.

Key words: Animals, Arthropod vectors, Climate change, Humans, Infectious diseases

Introduction

The term climate change is often used interchangeably with the term global warming. Climate change will alter the pattern of global infectious diseases. Climate exerts both direct and indirect effects on the appearance, and spread of many infectious diseases of humans, and animals (Shuman, 2011; Pal, 2013; Pal et al., 2013). The impact of climate change on the transmission and geographical distribution of vector-borne diseases, including zoonoses has been associated with changes in the replication rate, and dissemination of pathogen, vector, and animal host populations, which are sensitive to changing temperature and rainfall (Semenza and Menna,2009; Revich et al.,2012). The available evidence indicates the potential for an increasing challenge to public health from arthropod-transmitted diseases such as tick-borne encephalitis (TBE), West Nile fever (WNF), chikungunya fever, dirofilariasis and leishmaniasis (Ozer,2005; Myers and Patz,2009; Pal et al.,2014). Climate change is also increasing the threat of infections, such as bluetongue virus (BTV) in domesticated animals (Gage *et al.*, 2008; Dobson, 2009).

Climate change could be the biggest global health threat of the 21st century (Campbell-Lendrum et al., 2009). Climate variability causes death and disease through natural disasters such as heat wave, flood, and drought. In addition, many vector-borne and other infectious diseases are highly sensitive to changes in temperature, and precipitation. The impacts of climate change on human health will not be evenly distributed globally (WHO, 2003). The populations in developing countries are considered to be particularly vulnerable to several diseases. However, WHO emphasized that climate change is also likely to cause changes in ecological systems that will affect the risk of infectious diseases in the developed regions, including the seasonal activity of local vectors, and the establishment of (sub-) tropical species (Menne et al., 2008).

Climate interacts with a range of factors that shape the course of infectious disease emergence, including host, vector and pathogen population dynamics, land use, trade and transportation, human and animal migration, and these interactions complicate the attribution of effects (Lafferty, 2009). Some of the zoonotic pathogens such as Nipah virus, Hendra virus, Rift Valley fever virus, Hanta viruses, West Nile fever virus, *Listeria monocytogenes*, *Campylobacter*, *Leptospira*, *Salmonella*, *Yersinia*, *Cryptosporidium*, *Giardia*, *Fasciola* etc., are affected by climate change (WHO,2003; Pal,2007; Dufour et al., 2008; Semenza and Menne,2009; Revich *et al*., 2012; Pal and Abdo,2012; Pal et al.,2012; Pal et al., 2013; Pal et al.,2014). Therefore, surveillance is critical to predict potential outbreaks of vector borne diseases. This review focuses on the implications of climate change on the emergence and re-emergence of many vector borne diseases of humans as well as animals.

Plague

Plague (Black Death, pestilential fever) is a highly fatal re-emerging bacterial zoonotic disease, which is caused by *Yersinia pestis*, a Gram negative, non-motile, non-sporulated, rod shaped organism (Pal, 1995).

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The disease is mainly transmitted through the bite of rat flea (*Xenopsylla cheopis*) (Pal, 2007). Plague is the most important resurgent vector borne disease. The epidemic plague has resurged, most notably in Africa, with an average of nearly 3000 cases reported annually (Gubler, 1998). The disease has endemic foci in few African countries, such as Democratic Republic of Congo, Madagascar, and Tanzania, Asia and America. Since the beginning of the 1990s, the disease has reappeared in various countries, where no cases were reported for decades. Some of these countries such as Jordan, Algeria, and Libya are close to Europe. The threat of the re-emergence of plague foci on the European continent is unclear. More than 230 species of rodents can act as reservoirs of plague, and more than 80 species of fleas may be vectors of the disease (Pal, 2007). Climate definitely plays a role in the annual seasonality of plague. The re-emergence of plague in Congo and Uganda posed a serious threat to public health (Pal, 2007).The potential effects of temperature rise and drought (or abundant rains) associated with climate change on flea survival and reproduction, and on rodent prevalence are likely to be complex. How climate change will affect plague foci globally, cannot yet be predicted, and needs new research (Jones et al., 2008). Control of vector and rodent, environmental sanitation, vaccination, and health education will help in combating disease (Pal, 2007).

Dengue fever

Dengue fever (break bone fever) is a viral metazoonosis, which is caused by dengue virus (RNA) belonging to genus *Flavivirus*, and family *Togaviradae* (Pal, 2007). Disease is affected by climatic change and is reported from 100 countries. Outbreaks of dengue fever have been reported from Brazil, and Singapore. Currently, over 200 million people are at high risk of acquiring dengue fever (Pal, 2007).There are 50-100 million cases of dengue fever (Ozer,2005).The infection occurs following bites of mosquitoes of the genus Ades. In severe case, patient undergoes anoxia, hypovolemia, and shock, and death follows in 1to 2 days (Pal, 2007). Diagnosis is confirmed by virus isolation, serological, and molecular techniques. There is no treatment but supportive therapy is imperative in dengue haemorrhagic fever to save the life of the patient. Vector control, personal protective measures, immunization, and health education can help in the control of this fatal arbovial disease (Pal, 2007).

Rift Valley fever

Rift Valley fever (RVF) is an acute febrile viral zoonotic disease caused by Rift Valley fever virus (RNA), which belongs to Bunyaviridae family (Pal, 2007; Pal et al., 2012). Although human symptoms are usually mild, there can be haemorrhagic complications, and encephalitis. The disease is currently confined to Africa, with severe economic impact, and Saudi Arabia but is listed by OIE as second of the priority diseases whose incidence and distribution could be affected by global warming. An impact of

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climate change on RVF outbreaks might be anticipated to be mediated by the influence of increased rainfall on the habitat for vector mosquitoes but use of remote sensing satellite imagery to map rainfall and vegetation has achieved only partial success in predicting disease patterns across Africa. It seems likely that the interpretation of effects induced by climate change must take account of other variables, chiefly the effect of temperature on vector competence. It is important to mention that the geographical range of RVF has spread over the past 20 years, and it is possible that RVF may do the same, as West Nile fever, and bluetongue diseases in establishing in newly affected areas, including Europe (Senior**,** 2009). The outbreaks of RVF are usually associated with heavy rainfall, and warm temperature (Pal et al., 2013).

West Nile fever

West Nile fever is an emerging and re-emerging viral metazoonosis, and is caused by West Nile fever of genus Flavivirus and family Togavirdae (Pal et al., 2014). The disease was first identified in Uganda in1937, and is transmitted by the bite of mosquitoes of genus Culex (Pal, 2007). It is probably significant that WNV endemicity was achieved in the USA coincident with the hottest summer on record, an observation that is consistent with the explanation for other outbreaks in Russia and Romania, although collection of longer time-series data would aid interpretation (Myers and Patz,2008; Dobson,2009)**.**

Evidence is being collected to document the emergence and spread of mosquito-borne flaviviruses in central Europe. Globally, WNV is the most widespread flavivirus. However, despite a long-term presence in Europe, it has rarely been associated with clinical symptoms. However, in 2008 a relatively large outbreak occurred in northern Italy, affecting humans as well as birds, and horses; and in Hungary, spreading into Austria, there was an extensive outbreak of the virus in birds of prey, sheep, and horses with some human infections.The evidence suggests that the virus is now overwintering as a resident pathogen, and that climate warming will spread the infection such that Europe could face a situation with WNF similar to that in the USA (Dobson, 2009).

The emergence of other new flaviviruses in Europe is exemplified by Usutu virus, never previously observed outside (sub-) tropical Africa but associated in 2001 with an outbreak of avian mortality in Austria. This virus spread in bird populations within Austria up to 2003 and then declined, possibly attributable to the development of herd immunity. Although no human encephalitis was detected, there were cases of rash and specific antibodies measured in a significant number of asymptomatic individuals. The same viral strain has also now been found in Hungary (Dufour et al., 2008). During 1994-2000, epidemics of WNF meningoencephalitis occurred at a new alarming rate in North Africa, Europe, North America, and Middle East (Ozer, 2005).Currently, no vaccine is available to protect the humans.

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Tick-borne diseases

There is also increasing information in support of a correlation between climate change, tick activity and tick-borne diseases. *Ixodus ricinus* is the vector for 95% of tick-transmitted pathogens in Europe, mainly TBE and lyme borreliosis. Lyme disease caused by *Borrelia burgdorfer*, is transmitted by the bite of infected tick of the genus Ixodes (Pal, 2007).It is most commonly reported vector borne bacterial disese in Europe and North America (Ozer, 2005) However, further systematic study of the life cycle of *I. ricinus* and other ticks is needed to understand the potential for geographical expansion of the populations, and their link to disease (Jones et al., 2008).

Chikungunya fever

Chikungunya fever is a remerging viral metazoonosis, which was first described in 1952 from Tanzania (Pal, 2007).The etiologic agent, Chikungunya virus (RNA), belongs to genus Alphavirus, and family Togaviridae. After the latency of about 30 years, it has re-emerged again in India, and Malaysia (Pal, 2007). In India, over 1.25 million cases have been recorded (Pal, 2007).The increased incidence and geographical distribution of Chikungunya, most recently in Italy, might be interpreted more easily as a result of globalization, specifically the trade in used tyres, a good breeding ground for the vector *Aedes albopictus*, than as a specific consequence of climate change. However, a rapid spread of *Ae. albopictus* has been documented in the Balkans, France, Spain and Greece as well as Italy. Further insight on the impact of climate change will emerge from better mapping of vector distribution. There is also concern about the possible introduction into Europe of the mosquito *Aedes aegypti*, another important vector for the chikungunya virus as well as other arboviruses, such as dengue fever and yellow fever (Straetemans, 2008).

Japanese encephalitis

Japanese encephalitis (autumn encephalitis, brain fever) is an important arboviral zoonosis, which is affected by climate change, and is transmitted by the bite of infected mosquitoes of genus Culex, especially *Cx. triataeniorhynchus* (Pal, 2007). Culex mosquitoes can fly up to 5 kms. Approximately, 3 billion people live in endemic regions, and about 50,000 cases with 15,000 deaths are recoded every year (Pal, 2007).The epidemic of disease coincide with monsoon and post-monsoon period, when there is high density of mosquito vector. Maximum cases are recorded among children. The mortality rate ranges from 23 to 36% (Kabilan et al., 2000). The diagnosis of Japanese encephalitis is confirmed by using IgM-capture ELISA that detects specific IgM in cerebrospinal fluid or blood of patients within 4-7 days of

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onset of disease. RT-PCR is used for rapid diagnosis (Pal, 2007). There is no effective therapy but supportive care is recommended.

Yellow fever

Yellow fever (black vomit) is a fatal viral metazoonosis, and is caused by yellow fever virus (RNA), which belongs to genus Flavivirus and family Togaviradae (Pal, 2007). Human accidently gets infection by bite of infected mosquitoes of genus Haemagogus and Ades (Pal, 2007). The disease affects the primates as well as humans (Pal et al., 2013).The re-emergence of yellow fever in Peru has created a serious public health problem (Pal, 2007). Immunization of persons in endemic regions with 17 D chick embryo vaccine confers long lasting immunity. However, revaccination after 10 years is required (Pal, 2007).

Malaria

Malaria is probably the deadliest vector borne disease parasitic disease, which is climate sensitive. There were approximately 243 million malaria cases with 863,000 deaths in 2008 throughout the world. It is important to mention that 89 % of deaths due to malaria occurred in Africa. The annual economic cost of malaria has been estimated to be about US dollar 12 billion (Egbendewe-Mondzozo et al., 2011). The life cycle of malaria parasites is particularly sensitive to temperature, and this is an important limiting factor in malaria transmission and distribution (Patz *et al*., 2008). Biologically, the optimum temperatures for sexual development in mosquito vector, of various malaria parasites are 30^{0}C for *P. falciparum*, 22^{0}C for P. malaria and 25^{0}C for *P. vivax*. The malaria parasites do not develop at temperatures outside the 140-38¾ ^{0} C range. Furthermore, sporogonic development of P. falciparum in female mosquito ceases below 18-20^{0}C and below 14- 16^{0}C for *P. vivax*. The climatic factors also affect the survival and distribution of the vectors as well as influence the abundance of breeding sites and population densities. The warming due to shift in climatic variable could be anticipated to increase mosquito survival rates, parasite development, and disease transmission (Nwoke et al., 2007).

Deforestation in highland has serious consequences on malaria transmission in the continent. At the equatorial latitudes, such as the East Africa highland, malaria transmission may have emerged among the none- or low immune population-causing epidemic. Reports show serious epidemics of malaria in east and southern African highlands since 1988.The climate-linked malaria epidemic has occurred in Rwanda and Tanzania, and then, spread in western Kenya (Nwoke et al., 2007)

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Leishmaniasis

Leishmaniasis is an important protozoan metazoonosis caused by several species of *Leishmania* (Pal, 2007). Humans get infection by the bite of sand fly of the genus *Phlebotomus* (Pal, 2007).In Europe, two species of Leishmania cause endemic human disease: L. tropica (cutaneous leishmaniasis) in Greece and Turkey, and *L. infantum* (visceral leishmaniasis) in the Mediterranean area. Infections are usually asymptomatic (up to half the rural population in southern Europe is skin test positive), unless there is immunosuppression for example, clinical symptoms are associated with HIV co-infection. *L. infantum* is a zoonosis, and cats and dogs can be a major reservoir, with wild animals (jackals and foxes), and up to 35% of the rural dog population in southern Europe is seropositive. Although there is relatively little evidence yet to indicate an impact of climate change, there are data to show that Leishmania infections are spreading into temperate zones in Europe, being detected north of the Alps for the first time in 1999 (Ready,2008) .

Human African trypanosomiasis

The African trypanosomiasis (African sleeping sickness) is an important protozoan metazoonosis caused by Trypanosoma species (Pal, 2007). The infection occurs by the bites of infective tsetse fly of the genus Glossina (Pal, 2007).The tropical climate of Africa is favourable to most major vector-borne parasitic diseases including African human trypanosomiasis. The female tsetse fly vector of the disease, *Glossina* does not lay eggs like other flies; rather they give birth to young larvae on the floor of the tropical African vegetation, which is favourable to their survival. The young larvae burrow themselves into the top soil under the vegetation cover-wood, logs, leaves where they grow and develop to adult files. As the breeding, and survival of tsetse fly depends in the prevailing climatic variables such as temperature, humidity/ precipitation, soil type, vegetation cover, climate plays a vital roles in their geographical distribution of the disease (Nwoke et al., 2007).

The anticipated changes in global and region temperature, humidity, and wind pattern will directly affect tsetse fly reproduction, development, and longevity as well as the vectorial capacity to transmit the protozoa (Nwoke et al., 2007). With the global shift in climate variable, it has been observed that from 1953, the climatic conditions in the Sahel have become drier and harsher; the northern boundaries of tsetse fly, and African trypanosomiasis distribution have shifted 50-100 km southwards (Nwoke et al., 2007). The changes in land use consequent upon climate change and environmental degradation have created unfavourable conditions for the vector breeding and survival, and have contributed to changes in the pattern of the disease transmission and distribution.These observations have been confirmed by satellite remote sensing of Glossina morsitans using climate and vegetation indices. It showed a clear

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correlation between the predicted distribution of the vector flies and the human infection rates in African trypanosomiasis (Nwoke et al, 2007). Environmental sanitation is highly imperative to prevent breeding of vectors (Pal, 2007).

Dirofilariasis

Dirifilariasis is a helminthic metazoonosis, and transmitted following the bite of infected mosquitoes (Pal, 2007). *Dirofilaria repens* is the most frequent zoonotic infection in Europe and Asia. There is evidence for a growing clinical problem in northeast Europe because it appears that the parasite is now able to mature to the adult stage in humans whereas previously it had not usually done so. The public health problem is often not sufficiently appreciated. There is evidence that infections of *D. repens* decreased in some areas, for example in Italy during the past 20–30 years, but that *D. repens* is spreading throughout many other countries and that animal and human infections, in some cases very severe, are increasing. In addition, infections of *Dirofilaria immitis* are dramatically increasing and extending to previously unaffected areas such as Switzerland (Patz et al., 2008).

The changes in disease incidence are attributed to effects of temperature on the parasite itself, on the density of the vector population (and the emergence of *Ae. albopictus* as a competent vector) and to changes in human exposure. Recent research demonstrates that temperature dictates the development of Dirofilaria larvae in the vector, with a threshold below which development will not proceed and consequently determines the seasonal occurrence of heartworm transmission in temperate latitudes. Modeling studies predicting the potential for transmission to humans map the seasonal duration of risk across Europe and indicate that areas formerly free of the infection are now endemic. Better co-ordination between public health and veterinary health authorities, particularly to advise on the value of preventing infection in companion animals, will certainly tackle the issue (Randolph, 2009).

Conclusion

Climate change is an accepted fact that has affected all the ecosystems worldwide. It is now considered that climate change is the most important threat to humanity. Climate change occurs as a result of imbalance between incoming and outgoing radiation in the earth's atmosphere. Many infectious diseases including vector borne are climate sensitive, where their emergence in a region is dependent on climate related ecological changes. Most are zoonotic diseases of multiple etiologies, which can spread between humans and animals by arthropod vectors, wild or domestic animals, water and soil. It is recommended to enhance the capacity for monitoring potentially climate sensitive infectious diseases that are likely have the most impact on human and animal populations as well as arthropod vectors, and animal reservoirs.

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Public education can be used as a tool to illustrate easily avoidable dangers, such as providing a local breeding ground for mosquitoes by storing water in small household containers. It is imperative to conduct research into the relationship between weather, climate, ecologic changes and infectious diseases emergence in order to guide an early detection and intervention.

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