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Impact of Global Warming on Vector-Borne Diseases: Implications for Integrated Vector Management

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Introduction

Insect-borne diseases are the major causes of morbidity and mortality in several tropical and subtropical countries. Principally the devastating nature of malaria is indubitably intolerable [1]. The World Health Organization (WHO) has estimated the following global annual impact in the year 2009 as follows: Nearly half of the world's population is observed to be at the risk of malaria incidence. It has estimated that, in 2009, the number of cases of malaria was 225 million and the number of deaths was 781,000 [2], among which 50-100 million were dengue cases [3], and 120 million were filariasis cases [4]. The toll from other vector-borne diseases like trypanosomiasis, leishmaniasis, Japanese encephalitis, onchocerciasis and yellow fever add more millions of cases each year. It has been estimated that these diseases due to all parasitic and infectious diseases, represent 17% of the global disease burden, in terms of disability-adjusted life years [5].

In the 21st century, the emergence and re-surgence of vector-borne diseases still constitute an important threat to human health, causing over a million death and considerable and morbidity worldwide. Vector-borne diseases are linked to the environment by the ecology of the vectors and of their hosts, including humans. In the recent decades, climate change is a global phenomenon which has greatly influenced the emergence and resurgence of several infectious diseases such as malaria, dengue fever, plague, filariasis, trypanosomiasis, onchocerciasis, leishmaniasis and many arbo-viral diseases [6]. Since vector-borne diseases are climate sensitive, it has raised considerable concern over its implications on future disease risk.

Climate Change: Gloominess

There has been enormous progress in medical entomology ever since arthropods were shown to transmit pathogens to humans over 120 years ago. It is now accepted that vector-borne disease cycles are complex systems due to the requisite interactions between arthropod vectors, animal hosts and pathogens that are under the influence of environmental factors contributing to variation in disease transmission in complex ways. Vector-borne diseases will continue to evolve in a changing world as they have done throughout history. The vector-borne disease episystem encompasses all of the biological and environmental components and the aspects of the entire epidemiological vector-borne disease system within specified geographical and/or temporal scales [7]. Climate, i.e. temperature, precipitation, humidity, wind, etc. can influence various aspects of an arthropod vector's life cycle, including survival, arthropod population numbers, vector pathogen interactions, pathogen replication, vector behavior and of course vector distribution [7].

Impact of Global Warming on Vector-borne Diseases

The Swedish chemist, Svante Arrhenius, first predicted global warming in 1896 [8], that it is a gradual process that threatens to have serious consequences over time, including elevated sea levels, crop failure and famine, changes in global rainfall patterns, changes to plant and animal populations, and serious negative health impacts [9]. From the years 1906 to 2005, global average temperature has warmed by 0.74°C, and since 1961, sea level has risen on average by approximately 2 mm per year [10].

The impacts of climate change may occur over several time scales, ranging from the increased amplitude and stochasticity of diurnal or seasonal fluctuations in temperature and precipitation, particularly in temperate regions, to more stable increases in mean ambient temperatures over longer periods, particularly in tropical regions where many of the more concerning human diseases are endemic. The regions most vulnerable to the disease-related impacts of climate change are the temperate latitudes and the countries in the Indian and Pacific Oceans and sub-Saharan Africa, which will be disproportionately affected by extremes in temperature, and where public health programmes may be unable to cope up with the changes in disease transmission [11].

Global warming and increased rainfall contribute to the abundance and distribution of vectors like mosquitoes. Current evidence suggests that inter-annual and inter-decadal climate variability have a direct influence on the epidemiology of vector-borne diseases [12]. It has been estimated that the average global temperatures will have risen by 1.0-3.5°C by 2100, potentially raising the sea level to a maximum of 88 centimeters [13], increasing the likelihood of many vector-borne diseases [12]. If the water temperature rises, the larvae will take a shorter time to mature [14] and consequently there is a greater capacity to produce more offspring during the transmission period. This has serious negative implications for all aspects of human life, including infectious diseases [9].

The effect of global warming depends on the complex interaction between the human host population and the causative infectious agents [9]. Most vector-borne diseases involve arthropod vectors, such as mosquitoes, flies, ticks, or fleas. As insects are cold blooded, a marginal change in temperature can have a potentially large biologic effect on disease transmission. Furthermore, climate change can alter the incidence, seasonal transmission, and geographic range of diseases such as malaria, dengue and yellow fever (mosquitoes), leishmaniasis (sand flies), lyme disease (ticks), sleeping sickness (tsetse flies), chagas

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disease (triatomine bugs), plague (fleas) and onchocerciasis or "river blindness" (black flies). Schistosomiasis (involving water snails as the intermediate hosts) is also influenced by water temperature [15].

The prevalence and abundance of these vector-borne diseases are particularly sensitive to changes in mean ambient temperature since their transmission relies principally on the survival and reproduction of their invertebrate vector or intermediate host, and the parasite's incubation and survival rates therein. Since these vectors and intermediate hosts are incapable of thermoregulation, and their reproduction and survival rates are strongly influenced by temperature, small changes in temperature could greatly alter their distribution and abundance, resulting in a shift in disease patterns [16].

Within Africa, little evidence exists of causal changes in disease transmission and climate. This lack of evidence does not mean that these changes do not exist; rather, it may reflect the lack of available epidemiological data as a result of poor or absent surveillance and health information systems. Within Africa, 71.3% of the burden of disease is attributed to infectious diseases and malaria is observed to be the single greatest contributor (10.8%). All other vector-borne, helminthic, and environmentally related diseases that are affected by climate contributes to about 2% of the total burden of disease. With regard to environmentally related diseases in Africa, malaria contributes more than 80% of the cause of lost disability adjusted life years [3,17].

Describing the impact of global warming on all the arthropod-borne diseases, is beyond the scope of the present editorial article and is quite impossible as well as impracticable. However it can be implicated in terms of stunning examples like malaria and sleeping sickness. Although, insecticide and drug resistance have created resurgence and insurgence of many vector-borne diseases, in particular malaria, the role of global warming and its concomitant effects is quite immense [18].

Changes in temperature, rainfall, and relative humidity due to climate change are expected to influence malaria directly by modifying the behavior and geographical distribution of malaria vectors and by changing the length of the life cycle of the parasite. Climate change is also expected to affect malaria indirectly by changing ecological relationships that are important to the organisms involved in malaria transmission (the vector, parasite, and host). Recent evidence shows that changes in temperature and precipitation have already changed the distribution and behavior of the vector [19].

The problem of malaria vectors (Anopheles mosquitoes) shifting from their traditional locations to invade new zones is an important concern [20]. The temperature, rainfall and humidity are important determinant factors for the Anopheles distribution. A little increase in temperature leads to an increase in the mosquito's development and the adult frequency of blood feeding [21]. The Anopheles breeding and survival are determined and characterized by rainfall and humidity [20].

In 2008, the US Wildlife Conservation Society has identified African trypanosomiasis (sleeping sickness), a vector-borne disease of humans and animals, as one of the 12 infectious diseases likely to spread owing to climate change [22]. It is not only considered to be a major public health concern but also as a severe hamper for the socio-economic development. Rogers (1996) [23] modeled the effect of projected future climate changes on the distribution of three important disease vectors-mosquitoes, tsetse flies, and ticks-in southern Africa. Climatic change may alter not only the physiological constraints placed on the vector but also the ability of the parasite to survive within the vector [24].

Up to 77million more people could be at an increased risk of contracting sleeping sickness as the tsetse fly, transmitting the disease, spreads increasingly due to global warming [22]. Climate effects linked to global warming are expected to modify current distributions of triatomine bugs and the occurrence of Trypanosoma cruzi. Schistosomiasis is caused by the trematode Schistosoma mansoni. Currently, 600 million people are at the risk of infection by schistosome species and current research predicts that vector-borne diseases such as schistosomiasis will be particularly affected by changes in temperature [25,26].

Vector Control Challenges and Perspectives

It is essential to recognize here that there are major malaria control efforts underway at present in Africa; and indicators demonstrate remarkable success in malaria control in selected countries in West, East and Southern Africa [27]. However, history has shown that, there is a challenge in maintaining control. Therefore understanding the role of climate and environment on the potential for future disease risk is highly valuable [20]. Rogers's (1979) [28] analysis of the bioclimatic tolerances of tsetse flies may be used to determine how predicted patterns of climate change in tropical Africa might affect the distribution of tsetse flies and trypanosomiasis.

A recent study by Lafferty [2009] [29] has added into the long-standing debate on how global warming will affect the prevalence and distribution of human vector-borne diseases. This author's analysis suggested that Anopheles distribution range shifts are more likely to occur than range expansions. It is then clear that one of the major threats for the current functioning of the world is the uncertainty about the effects of global climate change. Working knowledge of where malaria vectors specially occur and will potentially occur in the future under climate change scenarios is very essential for the malaria control programme managers and policy makers [20]. No claim is being made that climate alone is the main determinant factor for Anopheles species existence. However, it is the only factor with available global data that provides an initial estimate of the potential range of Anopheles species [20].

Predicting how the long-term distribution and prevalence of such important human diseases will change in the face of global warming is a key challenge facing humans in the near future [16]. In the past decades, several endemic countries have experienced a significant decline in the incidence of vector-borne diseases due to modernization of healthcare services, improved housing and nutrition, better water management and living standards, greater access to medical service, rapid economic growth, modern technological development, access to health facilities, high awareness of people and support from international funding agencies.

However, long-term disease control strategy require extensive longitudinal surveillance systems capable of detecting (and dealing with) distribution patterns, ecological preferences, and behavioural trends of important vector species, which could significantly improve our ability to understand these transmission dynamics pattern and it could be useful for us to predict and employ the most appropriate vector control strategy in the near future. It should also strictly monitor the emergence and resurgence of vector-borne diseases, drug and insecticide resistance against agents and vectors, encompassing climate change particularly global warming.

Besides, insecticide resistance monitoring and management can be done by frequent susceptibility tests using diagnostic dose of insecticides and larvicides against proven insect vectors in order to apply new insecticide with novel mode of action to effectively contain the insecticide resistance and vector-borne diseases. This multi-scale approach may substantially strengthen the existing vector surveillance by helping allocate resources to vector-borne diseases prone areas in order to implement effective vector control interventions. It may be helpful to develop and implement new strategies that will accelerate vector-borne disease reduction and ultimate elimination. Besides, strengthening of the educational programs to encourage people of the endemic area to use appropriate preventive measures, preparation of rapid diagnosis kits as well as prompt treatment by potential drugs will help to combat the forthcoming epidemic.

The existing vector-borne disease control strategies are inadequate to deal with the negative consequences of global warming. In the recent years, the explosive global economic development, people movement, water projects, climate change and increased urbanization have substantially altered the disease transmission dynamics and pattern too [30]. Effects of global warming on ecosystems may substantially affect the propagation of infectious diseases associated with insect vectors, although complex factors affect the relationship between the spread of infectious diseases and ecosystem changes that have yet to be sufficiently clarified [31].

Indeed, global warming is a major environmental driver, which directly as well as indirectly attributes to entomological and epidemiological issues for disease transmission. It also influences the frequency and transmission dynamics of infectious diseases. In addition, it may play a pivotal role in sustaining the transmission cycle between vectors and human hosts by re-emergence of the vector, increased man-vector contact and parasite exposure to diverse strains. Therefore, at the moment control of vector-borne diseases is becoming a great challenge, demanding for novel innovative approaches like (1) consistent administration of integrated vector management; (2) identification of innovative user and environment-friendly alternative technologies and delivery systems; (3) exploration and development of novel and powerful contextual community-based interventions; and (4) improvement of the efficiency and efficacy of existing interventions and their combinations, such as vector control, diagnosis, treatment, vaccines, biological control of vectors, environmental management, and surveillance [32] to combat vector-borne diseases

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