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Climatic Variables and Malaria Transmission: Intricacies of Application

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ABSTRACT

Vector borne diseases are climate sensitive as the transmitting agent, mosquito/sand fly/tick are poikilotherms affecting their life cycle as well as the time taken in development of pathogen in their bodies. With the threat of climate change, there is renewed interest in understanding the link between climate and vector borne diseases. The studies are still limited owing to lack of multidisciplinary approach required for understanding the relationship between meteorology, modelling and transmission dynamics of vector borne diseases. Recent studies have opened up new vistas of opportunities as well as challenges and better understanding of the link between climate and mosquito vectors. The present review highlights the intricacies of main climatic factors, i.e. temperature, rainfall, relative humidity, wind velocity and radiation on the life of mosquito and subsequently transmission dynamics with example of malaria as one of the vector borne diseases, and need for further research.

Key words: *Vector borne diseases (VBD), mosquitoes, malaria*

1. Introduction

The climatic parameters have been found associated with transmission of vector borne diseases. The use of climate science in forecasting of malaria outbreak dates back to 1921 in Punjab. Later on Yacob and Swaroop (1944) developed the science further and provided forecast for malaria, based on rainfall and other indicators. In those days, meteorological data was integral part of health data and medical officers utilized meteorology for understanding the disease dynamics. After 1990, with greater awareness about climate change and its effect on human health and other sectors, scientists have started re-inventing the usefulness of climatic parameters in understanding the relationship between climate variables/ climate change and health aspects including vector borne diseases (VBD) so as to provide projections of future scenario and applications for early warning of disease outbreaks.

In India, there are six major VBDs, i.e. malaria, Dengue, Chikungunya, Kala-azar, Filariasis and Japanese encephalitis in addition to some re-emerging diseases like Kyasanur Forest Disease, scrub typhus and Crimean Congo Hemorrhagic Fever. Each VBD has some thresholds of temperature and relative humidity required for transmission, which determine their geographical distribution. In the recent years, it has been realized that the climatic thresholds (lower and upper) required for development of pathogen in the body of insects and the development of insect vectors i.e. mosquitoes, flies etc. are not fully known in case of same diseases like dengue, chikungunya, Kala-azar and Japanese encephalitis (IPCC, 2001). Further, with the generation of more knowledge, intricacy of using different formats of temperature and rainfall have also cropped up. In order to encourage the studies on relationship between climatic variables/climate change and vector borne diseases, a few problems related with climate variables and malaria are being highlighted in the present communication as an example of vector borne diseases.

2. Methodology

Literature dealing with specific and recent advances in relationship between climatic variables, i.e. temperature, Relative Humidity, rainfall, wind velocity and radiation for development of anopheline mosquitoes or malaria transmission from 1990 onwards was searched from google search engine. Full text of relevant publications was consulted from journals from library or downloaded (if free available).

3. Observations

3.1Temperature:

The data of temperature provided by the Indian Meteorological Department is in the form of daily, minimum and maximum. Various studies use such data by taking daily average and/or monthly average temperature (Bouma, 2003; Blanford et al 2013). Some researchers who do not have access to monthly time series epidemiological data of particular VBD, attempt to find out relationship between annual cases and annual temperature, which is not a desired method to find out the relationship between climatic changes and VBDs which are usually seasonal.

The extrinsic incubation period of a pathogen, (developmental time of pathogen in the body of insect vector) should be taken into consideration for deciding whether monthly or fortnightly data of temperature and disease incidence will be required for finding out the relationship. The correlation between average monthly temperature and monthly incidence of a vector borne disease, e.g. malaria is derived with month-to-month, one month and two months lag period and so on depending upon the geographical areas, i.e. humid to dry.

Further, immature stages of mosquito in water takes about ten days as optimum temperature in becoming adult. The adult mosquitoes after taking blood meal rest in human dwellings, cattle sheds or bushes. In this way, temperature of two habitats affect mosquitoes i.e. water bodies for development of immature stages and dwellings etc. for resting of adult mosquitoes (Fig 1).

In recent years, it has been found that the outdoor-recorded temperature is different from in-door temperature depending on the habitats and may vary from season to season. Further, the temperatures of water bodies are also different from the air temperature.

A recent study undertaken in Uttarakhand and Assam revealed the difference in outdoor and indoor temperature affecting the possible number of months during which the windows of transmission may open (Singh at el 2016). The diurnal temperature range has also been found critical in understanding the transmission dynamics of malaria (Paaijmans et al 2010).
The material of houses also affects the temperature of dwellings e.g. mud houses provides low temperature in summer, as

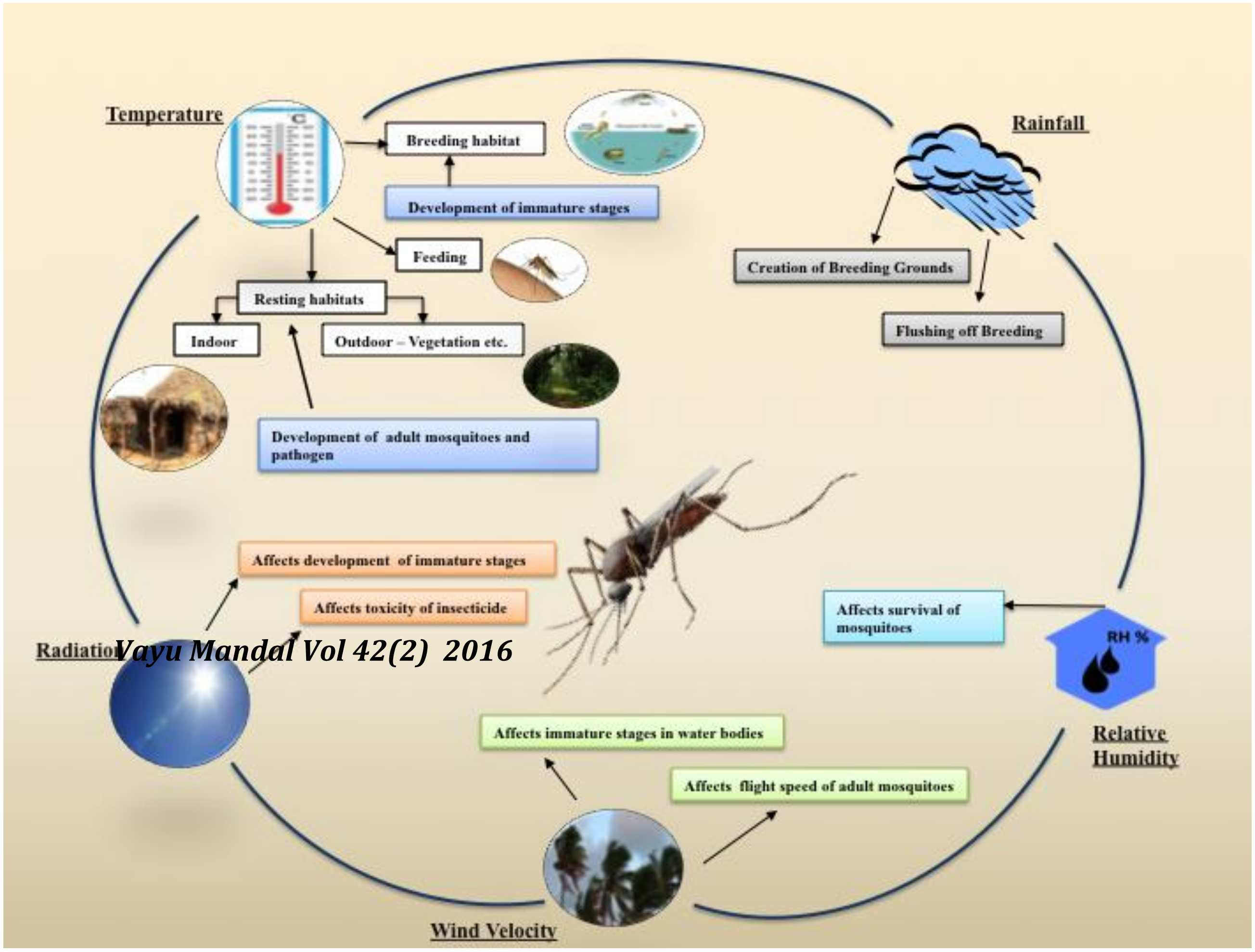

Fig 1 Possible effects of climatic parameters affecting life of mosquito and disease transmission

compared to cemented houses in the same locality. While in winters, the situation becomes reverse i.e mud houses are warmer than cemented houses (personal observations, unpublished data).

High temperature has been found helpful in faster development and longer survival of heat tolerant and malathion resistant Culex mosquitoes than susceptible strain (Swain et al 2008). The same was true with *Anopheles arabiensis* (Oliver and Brooke, 2017).

Therefore, the studies planned to develop models of transmission of malaria, due consideration should be given to incorporate temperature of water bodies, indoor /outdoor/ diurnal temperatures.

3.2 Rainfall

Rainfall has been found associated with outbreaks of malaria way back in 1921 when Gill documented his findings (Gill, 1921). The rainfall affects the vector borne diseases mainly in two ways i.e. either in creating breeding grounds for vector species in a rain deficient area like Rajasthan, Gujarat and Karnataka, rainfall creates breeding grounds and/or excessive continuous rainfall may flush off the existing breeding grounds (Paaijmans et al 2007).
Further, the amount and frequency of rainfall is very important in understanding its effect on creation of breeding ground for mosquitoes and role in outbreaks.

The stagnation of rainfall making it suitable as breeding habitat for a mosquito vector depends on the type of soil and the amount of rainfall. In geographic areas like West Bengal and Assam where soil is red (Udalfs) type, a little amount of rainfall can result in stagnation of water while in Rajasthan and Gujarat where the soil is sandy, water absorption capacity of the soil is high, therefore, water stagnates after continuous rainfall. In Kerala, the soil is of laterite type, which does not support stagnation of water for longer time.

The analysis of rainfall with vector borne diseases has been undertaken by various workers in a different way. One study attempted to find out relationship between reported annual cases of malaria with annual rainfall, which remained inconclusive (Singh and Sharma, 2002). It is quite likely to get no correlation with annual data of malaria cases and rainfall as the seasonality is masked. Further, if data are analyzed on month-to-month basis, i.e. cases of January and rainfall of January month, there may not be correlation, as the conducive conditions for transmission of malaria take one to two months (occurrence of rainfall →stagnation of water → breeding of vector species→ emergence of adult mosquito →feeding on infected human host → developmental time for pathogen in mosquito→ transmission to a healthy human host →getting symptoms → reporting at health facility), therefore, analysis with lag period is quite logical.

Since the vector borne diseases are climate sensitive and shows monthly fluctuations in their incidence, determining correlation coefficient between monthly cases and monthly rainfall with time lag period is ideal.

Rainfall has been identified as an important tool for early warning of malaria (Gill, 1921; Yacob and Swaroop, 1944; Laneri et al 2010). It has been observed that the rainfall at the threshold of transmission is critical. If heavy rainfall occurs during non-transmission or low
Transmission season, it will not affect the disease dynamics significantly. The critical

amount of rainfall, which can be conducive for outbreak of malaria, is not known for Indian conditions. However, in Africa 80 mm rainfall was found suitable for causing outbreak of malaria (Craig et al 1999).

3.3 Relative Humidity

Relative Humidity, which is indirectly governed by rainfall at a given temperature, affects survival of mosquitoes. For successful transmission of malaria, the infected vector species should survive for at least one week (Craig, et al 1999). If RH is low, the infected vector species will die before the completion of sporogony (development of malaria parasite in mosquito). The optimal conditions of RH required for development & survival of mosquito vector and transmission of malaria have been documented as more than 60% (Bruce-Chhwatt, 1980; Craig et al 1999; Grover-Kopec et. al. 2006). There are several publications on relationship between climatic variables and malaria, however, in recent years a few very specific publications highlighting the role of RH in malaria transmission have been published. Li et al (2013) found that one percent rise in RH resulted in 3.99% monthly cases of malaria. Effect of RH on decrease in survival of *Anopheles gambiae* mosquitoes beyond rainy season helped in development of seasonal pattern of mosquito abundance in Sahel region of Africa (Yamana et al. 2013). The authors proposed equations for the survival of *An gambiae* as a function of Temperature and RH.

3.4 Wind velocity

Wind current affects the development of immature stages (eggs, larvae and pupae) of mosquitoes in large water bodies like ponds, streams and ditches as the immatures stages might get driven away at the margins of water bodies in wind current. On the other hand, the flight of adult mosquitoes, which come out for egg laying in water bodies, swarming and feeding during evening and night time is also affected by wind velocity. If wind velocity is high, mosquitoes are likely to be drifted to long distances, affecting their feeding and resting behavior. Very few studies have been undertaken on these aspects, which can help in determining the spatial risk of malaria.

Mitdega et al 2012 attempted to study the impact of wind direction on larval density and malaria endemicity. They found that malaria infection was more when homesteads are upwind of larval sites. Bidling mayer et al. 1995 in Florida found that trap catches of adult mosquitoes were reduced by 50 % with wind speed of 0.5 m/sec and 75% at 1.0 m/sec. Catches of mosquitoes were inversely proportion to the wind speed, however, the threshold value of wind velocity could not be determined.

3.5 Radiation

Radiation from sunlight, particularly ultra violet rays affect the temperature of water bodies wherein mosquitoes breed. The chemical insecticides like Temephos; and biological insecticide, *Bacillus thuringiensis* which are used for control of immature stages are also likely to get affected. Very little work has been undertaken in this direction.Cohen et al (1991) in laboratory study found that irradiation of *Bacillus thuringiensis* var. kurstaki HD1 with 300-350 nm for up to 12 hr resulted in loss of toxicity of biolarvicide to larvae of *Heliothis armigera* mosquitoes.

Photoprotection of the toxicity of *B. thuringinesis* with melanin (negatively charged, hydrophobic, dark high molecular weight irregular biopolymer compounds, are produced by most organisms) has also been possible (Sansinenea and Ortiz, 2015). The findings suggest that stressed mosquitoes either due to insecticide resistance or high temperature are likely to survive more, warranting generation of evidence in malaria vectors species in view of projected rise in temperature.

The impact of sunshine on malaria cases also has been studied by Li et al (2013) in China. The authors found that one-hour rise in sunshine resulted in 0.68% increase in monthly number of cases of malaria.

4. **Conclusions**

Intricacies of temperature in terms of indoor, outdoor, water bodies, diurnal, nocturnal and in different types of dwellings need to be understood for vectors of different vector borne diseases. Detailed studies on frequency and amount of rainfall resulting in outbreaks in different geographic areas are warranted so that rainfall may be used as indicator for early warning of outbreaks of malaria and other VBDs. The impact of radiation on development of immature stages of mosquitoes and on insecticides' efficacy should also attract attention of vector biologists in view of threat of climate change.

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