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Malaria transmission in the hot arid Sahel North -Eastern Nigeria: The impact of climate

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ABSTRACT: Malaria transmission season in the Sahel is short and unstable such that immunity in the populace is unable to reach a high level. The possibility of severe malaria could be very high. In areas of low malaria endemicity, such as the Sahel, malaria infection is sensitive to some climatic and other environmental changes such as temperature, rainfall, humidity, meteorological and hospital data. Decades of prolonged drought, as experienced in the Sahel, have resulted in significant reduction of malaria prevalence rates from 50% to less than 10% in some areas with a resultant improvement in immunity to malaria.

Key words: Sahel malaria, Climate indices, Mosquitoe vectors, Northeastern Nigeria

Introduction

The early detection, containment and prevention of malaria epidemics constitute one of the four technical elements of the global malaria control strategy (WHO 1993). Following the failure of the malaria eradication campaigns in 1970's, the monitoring of meteorological indicators such as temperature, humidity and rainfall received renewed attention as part of early-warning systems for impending epidemics of malaria **(**WHO 1979, 1993**).** Currently there is no clear definition of a malaria epidemic thus posing serious operational implications for diseases control (Githeko et al 2001).

Over the past two decades, unacceptably high mortality and morbidity rates have been occurring during malaria epidemics when they are not immediately detected and controlled through interventions in areas of unstable malaria transmission in Africa. These unstable areas include places where transmission is limited by temperature, as in the East African highlands and by rainfall as in the Sahel **(**WHO 2001)**.** Thus; areas which were previously endemic for malaria are now vulnerable to malaria epidemics (Julvez et al 1997)

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Githeko and Ndegwa (2001) observed a relationship between the proportion of in-patient malaria cases and meteorological data. Unusual rainfall patterns could be inimical and so,
treatment facilities and vector control activities should be planned accordingly. Earlier studies revealed that malaria deaths and admission rates show seasonal fluctuations in the Sahel with the peak values occurring during the rainy season and low values in the dry season (Molta et al1995, Oguche et al 2001, Samdi et al 2005)

The Sahelian Environment

The dry belt of Nigeria, occupying some 38% of its total land mass, lies within the sudano-sahelian savanna of West Africa, which stretches from Senegambia to Somalia in the East- a land mass located within the co-ordinates: Latitude 10o to 14oN and longitude 30o to 140o East. This zone, generally known as the Sahel, is defined as the area that receives between 700mm and 800mm of rainfall per year (Gadzama 1991,Ezeugwu & Obiamiwe 2005, Ezeugwu & Okaka 2006).

The Sahel is considered one of the most sensitive and delicately balanced ecological systems in the world. Generally in areas of low malaria endemicity, the incidence of infections are far more sensitive to climate changes (Martens et al 1995). The variation of the annual rainfall is a very important factor influencing malaria transmission in the Sahel (Connor et al 1999). The areas of potential transmission of malaria are controlled by climatic factors such as temperature, humidity and rainfall (Bruce-Chwatt 1991, Eneanya 1998). This paper therefore reviews the impact of temperature, rainfall and humidity on malaria transmission in the Sahel with emphasis on how variability of climatic indices, hospital records and field data can be used as tools for detecting Malaria. Early Warming System (MEWS) - a strategy considered critical for malaria control in areas of unstable malaria such as the Sahel.

(1) Malaria and Temperature

Temperature affects the survival, development and life cycle of malaria parasites in the Anopheles group. All species have the shortest developmental cycles around 27-31oc (Bruce-Chwatt 1991, Gueye 1969) from a minimum of 8 days for *P.vivax* to a maximum of 15-21days for *P. malariae* and the lower the temperature,the longer the duration of the cycle (Bruce-Chwatt 1991). The minimum duration roughly doubles around 20^{o}C, below 19^{o}C for *P. falciparum* and 15-16^{o}C for the 3 other species, and consequently, the malaria parasites are not likely to complete their cycle and hence may not further propagate the disease as during higher temperatures.

Temperature also modifies the vectorial capacity of the *Anopheles*. Optimal values of temperature ranges are between 25^{o}C to 28^{o}C (Dutta et al 1978; Molineux 1988). The optimum temperatures lengthen the life span of the mosquitoes and increase the frequency of blood meals taken by the females to about one meal every 48 hours (Molineux 1988). Higher temperature also shortens the aquatic life cycle of mosquitoes (Kondrashim 1992) and reduced the time between larvae emergences and ovipositions as well as the time between successive ovipositions (Molineux 1988).

Studies in Maiduguri (Sara 1990, Ezeugwu & Okaka 2004, Ezeugwu & Obiamiwe 2005) showed that this area of the Sahel is characterized by a lengthy dry season of about eight months, with a mean annual temperature of about 27^{O}C. The study reported that the average optimum temperature for the development of mosquitoes was 27^{O}C and that development can be arrested completely at 10^{O}C or over 40^{O}C when high mortality may occur. Continuous exposure to high temperature (over 30^{O}C) reduced the average life span of mosquitoes. This was clearly observed between the months of March and June 1988 when there was a rapid decline in the population of mosquitoes collected in all sites (Sara 1990). It is also noteworthy that the lowest geometric means of asexual parasite density in a longitudinal parasitological study was recorded during this period of the year in Maiduguri (Samdi et al 2005). Gadzama (1977) also observed the same pattern during vector studies. However, negative correlation was observed between the number of mosquitoes caught and temperature in the Sahel (Sara 1990).

(ii) Malaria and Rainfall

Rainfall generally means new opportunistic breeding places. Nonetheless, rainfall can also destroy existing breeding places as heavy rains can change breeding pools into streams, impede the development of mosquitoe eggs or larvae or simply flush eggs or larvae out of the pools. Conversely, exceptional drought conditions can turn streams to pools and the appearance of such opportunistic vectors' breeding sites sometimes preceded epidemics (Bruce- Chwatt 1991, Ezeugwu and Obianwe 2005). The Garki Malaria project which spanned a period of six years and included the 1973 drought period served as an example as it was possible to observe the effect of low rainfall on malaria in the Garki District of Kano State (Betterton and Gadzama 1981). Of the mosquito species found in Garki area, three were considered to be major malaria vectors. These were *Anopheles funestus* and two sibling species of *An.gambiae.* The two siblings look alike, but one tolerates dry conditions of the Sudan savanna more than the other and they also differ in the aspect of their biology and behaviour (Desowitz 1980).

It was found that the numbers of *An.funestus* were significantly severely altered during the drought years unlike *An.gambiae* (Molineux & Gramicca, 1980). This was probably due to the difference in the breeding habits of the two species. *An.gambiae* prefers semi-permanent waters in the Sahel with vertical aquatic plants such as reed, whereas, *An. gambiae* will breed in the small puddles left by animals hoof prints and the like (Desowitz 1980 Nwoke et al 2007)). In times of drought, there would be insufficient water to establish *An.funestus* breeding sites, but even a small amount of rain would be sufficient to create sites suitable for *An.gambiae* to breed thus, it is erroneous to believe that malaria, as water related disease is necessarily reduced by a period of drought (Betterton & Gadzama 1981). Repeated rains cause severe flooding resulting to temporary flushing out of breeding places. Consequently the breeding of a vector population is greatly reduced, but becomes re-established when favourable conditions are restored (Gadzama 1983,Ezeugwu & Obiamiwe 2005).

(iii) Malaria and Relative Humidity

The interaction between rainfall, evaporation, runoff and temperature modulates the ambient air humidity, which in turn affects the survival and activity of Anopheles mosquitoes. To survive, they need at least 50% relative humidity (Gueye 1969) or 60% humidity (Bruce- Chwatt 1991, Dutta et al 1978, Molineux 1988). Higher levels lengthen the life span of the mosquitoes and enable them to infect more people (Dutta & Dutta 1978). In the Sahel, Sara (1990) and Umaru et al (2007) observed that a constant high temperature and low relative humidity led to drastic decline in the mosquitoes populations between March and May as the hot dry period could affect their life-span, reproductive and feeding capacities. Most of the breeding grounds dried up during these months. Insect activities are correlated with daily rhythm of temperature and humidity. Such rhythm is most evident in areas prone to hot and relatively dry days as the Sahel which incidentally includes Maiduguri area (Anderson 1982; Gadzama 1977)

(iv) Malaria Versus Meteorological and Hospital Data

Githeko and Ndegwa (2001) showed that it is possible to create a simple malaria epidemic prediction model needing no special equipment or skills but only meteorological data and hospital records of malaria in-patients. This can be adopted by existing health personnel using readily available temperature and rainfall data of the meteorological department throughout the country. The task of developing such a malaria prediction model in the Sahelian north-eastern Nigeria, where it is most needed, remains paramount. In Namibia, it has been noted that rainfall data (quantity and distribution) is a good indicator of malaria morbidity. In particular, a close relationship exists between cases of infection and number of rainy days. The rainfall quantity and wetness ratio also gave significant relationship with malaria morbidity and this analysis also suggested that in Namibia rainfall data could provide an early warning system for malaria epidemics (WHO 2001).

While it is much easier to obtain fairly good data from the meteorogical agency, the same cannot be said of hospital records in the Sahel. This is a major setback in developing malaria early warning systems (MEWS) for the Sahel. Anyanugwo and Kalu (1997) highlighted the common problems of diagnostic laboratories in the Sahel with respect to malaria namely:

(i) The recording of false positive owing to dirty slides

(ii) Inappropriate storage between smear preparations and microscopic examinations

(iii) Malpractices such as dumping of slides and consequent guesswork which are noticed to be common especially in commercial diagnostic laboratories.

(iv) Inexperienced (untrained//unskilled) technical staff employed by private laboratories.

(v) Insufficiently equipped laboratories.

All these factors have direct negative effect on the value of hospital record kept to be consulted later for research purposes. The value of good hospital record keeping in the Sahel was further elucidated in a malaria-related study by Molta et al (1995) on hospital attendance, admissions and deaths in five selected surveillance centers in northeastern Nigeria by studying records of cases that occurred during 1989-1990. Inspite of the setback sufferred by this work due to incomplete data which prevented extensive statistical analysis, the work revealed the valuable potential of hospital records in malaria forecasting in the Sahel. The monthly figures of malaria among in-patients showed seasonal fluctuations: low values during the dry seasons and high values in rainy season. This is not surprising as the biting density and infectivity rate of the vectors intensified during the rainy seasons. The study further showed that the death figures demonstrate similar seasonal fluctuations to those of malaria admission. In essence the peak value occurred during the rainy season and dipped during the dry season.

An early detection system based on malaria data recorded on a monthly or weekly basis within the health care facilities is an urgent requirement. If the surveillance system, laboratory procedures, data analysis reporting and notification are well established, control measures can be taken as soon as possible. Inevitably, there may be some delays after the onset of the epidemic (WHO 2001).The experience of malaria epidemic forecasting in the Indian subcontinent and its relevance to the Africa situation was outlined by Connor et al (1990) who proposed that monitoring of population vulnerability would increase awareness of the use of Malaria Early Warning System (MEWS) as a tool for malaria control in Africa.

Conclusion

For now, inspite of the obvious benefits of intersectorial collaborations between health services and meteorological agencies, the discipline that links weather to disease is still in its infancy and therefore,the few health, professionals, agriculturists and meteorologists should collaborate to share the same technical language and communicate effectively. To confirm seriousness about the need for development of environmental information systems for epidemic diseases such as malaria, this training and collaborative vacuum must be addressed (WHO 2001)

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