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Review Article

Climate change and malaria control: the importance of mitigation and a call to action

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ABSTRACT

Malaria has remained an important target for global disease control efforts for decades. The streams of funds and, consequently, availability of effective interventions for the disease have resulted in considerable reduction in its burden, globally. Despite the relative success of such global efforts, malaria remains a significant threat in over a hundred countries, worldwide, leading to about one million deaths and hundreds of millions of hospital visits, annually. Many researchers and health commentators have argued that global warming, a consequence of climate change, could be linked – directly or indirectly – to the persistence as well as the re-emergence of malaria epidemics. Although the association between climate change and malaria spread is complex and remains a subject of controversy and debates, this paper argues that the spread and severity of malaria in several places and the increased incidences of the disease in some regions could indeed be associated with the effects and consequences of climate change. The paper maintains that the biology of the *Plasmodium spp*, the ecology of mosquitoes, and even the susceptibility of humans to malaria could all be affected directly/indirectly by extreme climatic events. Based on the growing body of evidence on this subject, this paper makes a call for all stakeholders to come to a consensus on the significance of climate change mitigation to malaria control, and offers some recommendations on the way forward.

Key words: Malaria, Climate change, Mitigation, Malaria-climate change, Position statement

INTRODUCTION

Following the resurgence of funding and the availability of affordable interventions for malaria control, current evidence reveals a substantial reduction in the global burden and endemicity of the disease.[1,2] However, with studies associating the existing morbidity and mortality rates of malaria with climate change – and several others demonstrating, through model predictions, a likely increase in the intensity and future range of the disease.[3] There is a growing concern about the potential impacts of climate change on malaria epidemics.[4-6] Granted that the causal relationship between climate change and the increase in the incidence of malaria is complex and debatable, the need for proactive measures to mitigate its possible effects on health, in general, and malaria, in particular, is nonetheless imperative.[5,7,8]

The need for mitigation becomes, even more important in view of the consistent evidence in support of the direct and indirect health impacts (infectious diseases inclusive) of climate change[9] and explains the necessity for this study. This paper is a wake-up call on the possible role of climate change in malaria epidemics. By drawing on current literature, the paper aims to awaken the consciousness of all stakeholders in malaria control to the importance of mitigation and the need for a position on climate-malaria relationship. Subsequent sections in this paper highlight the reality of climate change, and the problem of malaria. Also, the paper discusses possible

health impacts of climate change, the importance of climate change mitigation to malaria control, concluding with a call for all stakeholders to take a position on this subject.

METHODS

A search of the literature to retrieve sufficient articles and publications was conducted using the online databases of PubMed, Science Direct, Web of Knowledge and Google Scholars. A combination of terms relevant to the topic was used including, but not limited to 'climate change and malaria', 'global warming and malaria', 'health impacts of climate change', and 'climate change mitigation'. Journal articles reviewed were those published in the English language, relevant to the topic, peer reviewed and with complete text availability. These include research articles, systematic reviews, commentaries and other academic reviews. In addition, relevant web pages on malaria as well as on climate change were visited for data, reports and publications. Key reports from the intergovernmental panel on climate change as well as from World Health Organization were accessed. A few studies were obtained by searching the reference lists of some of the high-quality publications. Similarly, appropriate e-books were examined and information extracted from them where deemed relevant.

The reality of climate change and its relationship with malaria epidemics

In the past decades, research in climatology has consistently demonstrated a progressive rise in earth's temperature, a concept known as global warming.[10] Global warming – an increase in earth's mean temperature – is consequent upon the growing emission and accumulation of atmospheric greenhouse gasses.[4] Evidence suggests this phenomenon has contributed significantly to changes in climatic conditions with a range of ecological consequences[11] such as sea level rise, melting glaciers and polar ice cap, shortage of freshwater bodies, bleaching of coral reef, changes in the weather system, and so on.[4,9,]

As observed by the intergovernmental panel on climate change (IPCC), from 1750 to 2000, there was an increase in the atmospheric concentrations of carbon dioxide, nitrous oxide and methane (greenhouse gasses) by about 31%, 17% and 151%, respectively.[12] These changes resulted in 0.6-degree centigrade rise in global mean temperature over the 20th century. This is global warming, an evidence of climate change.[8] Besides its effects on physical systems and the ecosystem, climate change has considerable impacts on human health,[13] and while it may not be entirely generalizable, climate variability among other factors is considered to be responsible for malaria incidence and/or persistence in many countries.[8]

Health impacts of climate change

Climate change affects human health in diverse ways, directly and/or indirectly.[14] In the first instance, extreme events of temperature and rainfall could result in heat waves, flooding and drought.[14] These have direct, immediate as well as possible long-term impacts on human health, ranging from injury and exacerbation of cardiovascular diseases to heat-related illnesses and premature mortalities.[10] These extreme climatic events may equally affect the epidemics of malaria favorably or otherwise.[8]

Secondly, effects of climate change like flooding, heat waves, and cyclones, may bring about considerable damage to health care facilities and social infrastructures – electricity, roads, houses, and so on.[11] Besides their impacts on mental health,[15] damage to social infra structures may result in substantial changes in socio-demographic variables, with possible economic consequences.[16] Given the inextricable link between health and socioeconomic as well as socio-demographic factors,[17] the adverse effects of these impacts on public health are predictable – poor funding, stresses on healthcare services and health infrastructures, risks to global security, and so on.[17,18] Other health impacts that have been linked with climate change include an increase in the incidences of waterborne, foodborne and vector-borne diseases following changes in rainfall pattern and temperature increase.[11]

Also, climate change may contribute to air pollution by increasing the level of air pollutants.[19] A ready example would be the incidence of a higher tropospheric ozone pollution in some regions around the world.[19] Air pollution potentially increases the risk of respiratory tract infections/diseases.[10] Also, sea level rise – another important consequence of climate change – may lead to flooding, drought and environmental degradation.[20] All of these effects could result in population displacement which may, in turn, contribute to the spread and increase in mortality rates of infectious diseases, like HIV/AIDS and malaria.[20,21] As observed by the World Health Organization (WHO), a few developed countries like Australia will have a fair share of the health impacts of climate change; however, the impacts will be worse on countries in the less developed regions of the world, especially, among the vulnerable sub-populations.[14]

The problem of malaria

Malaria is an infectious disease caused by a unicellular organism known as Plasmodium and transmitted by the bite of infected female Anopheles mosquitoes.[22] The epidemiology of the disease depends on the biology of the causative organism (plasmodium), the ecology of the vector (female anopheles mosquitoes), immunity of the host (partly a function of nutritional status) and climatic factors – rainfall, humidity and temperature.[23] Malaria is present in over a hundred countries around the world,

responsible for about a million deaths, and hundreds of millions of clinical cases, annually.[5] At present, the burden of malaria remains unacceptably high in developing countries, especially, for those in sub-Saharan Africa where about 89% of malaria cases were recorded in the year 2015.[24] Currently, about half of the world population is estimated by the WHO to be at risk of the disease.[24] Hence, malaria remains a disease of global public health importance.

The climate-malaria connection

There is an on going relationship between climate and malaria.[4] Both the causative organism (Plasmodium) and the vector (mosquitoes) depend significantly on climatic factors like temperature, rainfall and humidity.[5,7,23] For the optimal development of mosquitoes, a temperature range of 20-30 degree centigrade together with high humidity, food availability and stagnant water pools are necessary.[4] Similarly, the development of Plasmodium within mosquitoes is highly sensitive to the surrounding temperature.[6] The time it takes for Plasmodium to develop decreases as temperature increases.[9] Hence, global warming may be contributing to the incidence of malaria,[9] although this is highly contested.[4,25]

The impacts of climate change on malaria are already evident as many researchers contend.[10,26] Evidence to support such contention would include the case of malaria resurgence in the highland tea estates of Kenya, where the disease had disappeared for about thirty years.[4] While it is important to understand the dynamics of malaria incidence and prevalence from other perspectives like resistance to drug/insecticides, changes in land use, vegetation/other environmental factors, socioeconomic status, funding, and so on,[1,8] it is equally imperative to acknowledge the role of climate change.[4]

Perhaps the climate-malaria relationship is best demonstrated by the phenomenon of El Nino-Southern Oscillation (ENSO).[26] ENSO refers to the increased warming of the sea surface in the central and eastern equatorial Pacific, bringing about a considerable variation in climatic factors.[10] The phenomenon exhibits an important relationship with the epidemics of vector-borne diseases, and this understanding is critical to developing early warning systems from seasonal climate forecasts.[10] Recent changes in the frequency of El Nino and the previous changes in its intensity from 1975 are probable manifestations of the effect of climate change.[10] This change in frequency and its impact may be connected with malaria outbreak, particularly, the re-emergence of malaria in Venezuela[27]. In line with the findings of Bouma, Dye[26], the incidence of malaria in Venezuela increased by more than 30% in the year following a Nino event, offering a valid argument for a possible association between climate change and malaria epidemics.

Also, in their study on "climate change and mosquito-borne diseases in China", Bai, Morton, Liu[28] found that all the studies reviewed except one reported a correlation between malaria and climate variables. According to this study, the most significant climatic determinants for malaria transmission was temperature. In almost all of the reviewed studies, temperature exhibited a positive association with malaria.[28] A recent study in Port Harcourt region, Nigeria, equally found a significant relationship between the prevalence of malaria and increase in rainfall and temperature.[29] The study reported a three centigrade rise in temperature as well as increase of 1581 mm of rainfall from 1950 to 2014, resulting in a corresponding upsurge in the prevalence of malaria in the study location.

A critical analysis of the available evidence, however, reveals that climate change could potentially increase or decrease malaria incidence depending on the location, the level of change in climatic factors and the malaria control efforts, among other factors.[2,5] For instance, while a suitable combination of climatic factors – temperature, humidity and rainfall – favours the survival and multiplication of malaria vector and parasite,[7,11] extremes of same factors may inhibit the survival of mosquitoes, and hence, Plasmodium.[8,11] Given this fact, it can be inferred that climate change is a significant factor in the incidence, transmission and the distribution of malaria.[27] Hence, the importance of mitigation.

Health benefits of climate change mitigation

Mitigation of climate change is about strategies used in limiting human-induced global warming from increased emission of greenhouse gasses.[30] There are a number of such strategies – switching to renewable energy sources, reforestation, environmental management and improved land use, energy efficiency, and so on.[30] The benefits and co-benefits of mitigating climate change are many and varied. First, changing sources of energy from the traditional biomass fuels such as wood and charcoal, to sun and other renewable sources, especially, in low-income countries, could significantly reduce the rates of deaths from indoor air pollution, besides cutting out the extended time spent by women and children in collecting woods and other fuels.[11] Thus, this change may contribute substantially to a reduced incidence of respiratory tract diseases in addition to many other economic as well as environmental benefits.[11]

Second, a change in transport policy that encourages an active transport system-walking, cycling and rapid transit systems will result directly in less traffic injury, low noise stress, weight reduction (benefitting cardiovascular health, and reducing obesity and diabetes), and improved air quality (reducing respiratory tract diseases).[31] The significance of these benefits become evident when considered against the burden of traffic-related mortalities – about 2.6 million annually.[32] Also, given that cardiovascular diseases and diabetes are among the leading causes of morbidity/mortality in the world, the possible benefits of climate change mitigation in relation

to the diseases are highly desirable.[10] Moreover, this change in policy could substantially reduce the level of carbon emission from automobile engines, and so has other direct and indirect health benefits.[33]

Third, through reforestation – an effective carbon sink strategy – the increasing increasing concentration of atmospheric carbon dioxide can be offset.[34] Clearly, afforestation plays a crucial role in mitigating the impacts of climate change. Being a critical component of the global carbon cycle, forest ecosystems, on a yearly basis remove about three billion tons of anthropogenic carbon.[35] Since carbon dioxide is one of the greenhouse gases with potential for increasing earth's mean temperature, lowering its atmospheric concentration is fundamental to preventing global warming.[34] Hence, afforestation has considerable implications for reducing global warming, and the associated health impacts.[34] In the estimation of the WHO, a one-degree rise in global temperature above the pre-industrial levels will result in a 100% increase in annual climate-related mortalities.[33] It is logical, therefore, to expect a commensurate long-term reduction in climate-related deaths following the active and sustained practice of afforestation and other climate change mitigation strategies.

Lastly, a shift from the use of fossil fuel to renewable sources could potentially benefit human health by reducing the level of greenhouse gas emission and air pollutants (particulate matter, ozone, methane, nitrogen oxide and sulphur dioxide).[11] As demonstrated in a study in the United States, powering vehicles with renewable energy sources could save 3700 to 6400 lives on a yearly basis (that is, through air pollution reduction).[36] Other direct and indirect benefits of climate change mitigation include a decrease in the levels of infectious diseases (malaria, dengue, cholera, and so on), improved quality of life, an increase in life expectancy, lower pressure on the healthcare system (fewer admission, lesser consultation) and so on.[37]

Benefits of climate change mitigation in malaria control

Climate change mitigation could further benefit malaria control in many ways.[38] First, the adverse impacts of climate change on agriculture and the ecosystem – decreased water availability, geographical shifts, yield reduction and increased risks to pests – could lead to food insecurity which in turn leads to malnutrition (undernutrition).[39] Food insecurity and malnutrition debilitate the immune response, making people more susceptible to malaria (and other) infections.[40] For those already suffering from malaria, malnutrition worsens disease prognosis by exacerbating the severity of the infection. [41] Thus, through a direct positive impact on food security, climate change mitigation could contribute to the improved nutritional status which in turn enhances the success of malaria control through a synergistic relationship with other malaria control measures.[40]

Second, extreme events like heat waves, flooding and drought often result in population displacement.[11] Studies have suggested that large-scale migration of people is a significant risk factor in the spread of infectious diseases like HIV/AIDS and malaria.[21]

Hence, mitigation of climate change can contribute substantially to the reduced incidence of mass migration of people, and indirectly to the epidemics of malaria. Third, environmental degradation consequent upon climate change provides a favourable environment – food shortages, indulgence, and migrations – for the spread of infectious diseases like malaria and HIV/AIDS.[11,42] Lastly, as previously discussed in this paper, increase in extreme climatic events portends significant risk for malaria incidence and prevalence, mitigation is one promising approach to limiting the effects of these extreme events and consequently to minimising their possible contributions to malaria epidemics as well as to other infectious diseases.[43]

A call to action

Based on the climate-malaria connection and other health effects of climate change, highlighted in this paper, stakeholders in health, particularly in malaria control, can no longer sit on the fence. The necessity for a consensus on the impacts of climate change on malaria epidemics and the importance of mitigation is now apparent than ever. Every stakeholder would need to take a position on this subject with the understanding that:

- Climate change is real and remains a considerable threat not only to the environment but human health in general and malaria epidemics, in particular.[8,26]
- Although the climate-malaria relationship is complicated, and epidemics of the disease depend on many other variables, climate change nonetheless portends significant risk to malaria incidence, emergence and re-emergence in many countries.[27]
- The effects of climate change on malaria will vary with geographic locations, and while the burden may decrease in many areas where precipitation is projected to decrease, it will increase significantly in areas where temperature and precipitation are projected to be unusually high.[7,27]
- A few developed countries will have a fair share of the health impacts of climate change; however, the impacts will be worse in the developing countries, especially among the most vulnerable sub-populations; for instance, sub-Saharan Africa, where malaria is already ravaging lives.[14]
- Mitigation of climate change is critical to the long-term reduction of human-induced global warming and its potential impacts on human health, particularly, the epidemics of malaria.[43]
- Switching from the usual fossil fuel to the renewable energy sources, together with other measures for reducing the emission of greenhouse gasses may

contribute substantially to reducing the health impacts of climate change and the burden of malaria.

Recommendations

In view of the importance of the discourse in this paper, it is recommended that all stakeholders in health care, the Roll Back Malaria Partnership, health professionals, and other bodies (both governmental and non-governmental) be involved in:

- Promoting the awareness of the impacts of climate change on health in general and malaria in particular, and the understanding of the benefits/co-benefits of climate change mitigation on malaria control,
- Promoting, among health professionals and partners in malaria control, a sustainable and environment-friendly strategies for malaria prevention and control,
- Funding and supporting further studies and researches on climate-malaria relationship as well as on better mitigation strategies,
- Advocacy for countries to adopt and ratify international policies aimed at decreasing the emission of greenhouse gasses,
- Surveillance and monitoring the impacts of climate change on the malaria epidemics,
- Not only must stakeholders take a position on this subject, such must as a matter of policy, be made clear and unmistakable by the provision of relevant as well as accessible position statements, for instance, on websites of stakeholders.
- The government and health sector leaders must take urgent and necessary actions in the form of policy, regulations and programs to reduce or limit the levels of emission of carbon-dioxide and other greenhouse gases from fossil fuel,
- Each country should develop their own national strategies on health and climate change and implement same for effective response to the prevention, incidence, emergence and re-emergence of malaria.

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