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Editorial

Climate change and the rising incidence of vector-borne diseases globally

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As the world experiences warmer weather, heat waves and flooding, the climate change is leading to the geographical expansion of mosquitos, which are known vectors of a range of infectious diseases like dengue, malaria, chikungunya, yellow fever, rift valley fever, West Nile fever, Japanese encephalitis and Zika which affect millions of people worldwide [1]. Climate change now threatens the spread of vector-borne diseases to previously low-risk areas in Africa, Asia, Europe, and the Americas [2–7] According to the World Health Organization (WHO), an additional 250,000 deaths per year will occur in the next decades as a result of malnutrition, heat stress and vector-borne diseases [8]. World leaders have now acknowledged that the climate crisis is a health crisis, and on 3 December 2023, the first-ever 'Health Day' dedicated to tackling the health impact of climate at a UN Climate Conference (COP) was hosted by the UN climate conference (COP28) that took place in Dubai, UAE, from 30 November to 12 December 2023 [9]. By December 3, 2023, 123 countries had endorsed the COP28 UAE Declaration on Climate Change and Health, expressing their grave concern about the negative impacts of climate change on health [9].

As the climate crisis escalates, diseases transmitted by *Aedes, Culex* and *Anopheles* mosquitoes will likely expand their reach and significantly impact human health and wellbeing [2-4,10]. *Aedes aegypti*, the yellow-fever mosquito that originated in Africa [11], does not only carry yellow fever, but is also a vector of West Nile virus, chikungunya, dengue and Zika [7]. This species is now found in tropical, subtropical and temperate regions worldwide and has recently been incriminated as a vector of Zika [7]. In the Southeast Asian region, *Ae. aegypti* is the principal vector of dengue. It is well adapted to living near human populations in rural and urban areas and breeds in human-made containers that hold water, such as tires, buckets, and flowerpots, where they lay their eggs [11]. *Aedes albopictus*, the Asian tiger mosquito, is regarded as a secondary vector of dengue and is now considered as one of the most invasive species globally because of its strong ability to adapt to new environments [11]. It is native to tropical and subtropical areas of Southeast Asia and breeds in natural habitats, including tree-holes, bamboo stumps and at the edges of tropical forests [11]. It is, however, a highly adaptable species and, in recent years, has spread to Africa, Europe and the Americas through travel and sea trade and adapted to breeding in rural areas and human-made containers in urban settings [12]. It has now genetically adapted to become a competent new vector of dengue and Chikungunya viruses [12]. In

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Africa, the South Asian malaria vector, *Anopheles stephensi*, was described in Djibouti in 2012 but is now raising concerns after appearances in six other countries in Africa (Ethiopia, Ghana, Kenya, Nigeria, Somalia and Sudan) where malaria is endemic [13–15].

The incidence of dengue, a vector-borne disease transmitted by *Aedes* mosquitoes, increased dramatically from 500,000 cases in 2000 to 5.2 million in 2019 [10]. A recent report by the European Centre for Disease Prevention and Control (ECDC) also demonstrated the spread of different mosquito vector species that can cause many mosquito-borne diseases [3]. As summers got longer and warmer, and heat waves and flooding became more common in recent years, there was a notable rise in dengue cases globally. As of October 2023, over 4.2 million cases and over 3, 000 dengue-related deaths have been reported from 79 countries/territories globally [3]. Across Asia, nations like Bangladesh, Sri Lanka, Thailand, and Malaysia have experienced a surge in cases of mosquito-borne diseases [16]. South America has been severely affected by dengue in 2023, with Peru grappling with its most severe dengue outbreak on record [17]. In Florida, USA, a rise in dengue cases prompted authorities to issue alerts in several counties [18].

The recent outbreaks of dengue in Bangladesh exemplify the impact of climate change on the changing micro-ecology of the *Aedes* vectors and the rise in the risk of mosquito-borne infections in southeast Asia. A World Report published in The Lancet in August 2023 [19] predicted that Bangladesh will register record numbers of dengue cases in 2023 amid an accelerating outbreak. In October 2023, Bangladesh experienced its worst dengue outbreak on record when more than 1000 people died, and for the first time, more cases were recorded away from the dense urban centres [20]. In contrast, only 281 deaths were recorded in 2022 [19]. The epidemiological profile of dengue in Bangladesh has the infection typically peaking during the monsoon season between July and September. The typical dengue peak during the monsoon season shifted in 2023, starting three months earlier, due to favourable breeding conditions for the *Aedes* mosquitoes caused by a prolonged monsoon season with higher temperatures and irregular heavy rainfall.

In Europe, as heat waves and flooding became more common in recent years, and summers got longer and warmer, *Aedes albopictus* was able to establish itself more northwards and westwards [3]. Also, the yellow-fever mosquito, *Aedes aegypti*, which is known to transmit dengue, chikungunya, Zika, Mayaro and, potentially, West Nile viruses, has been established in Cyprus since 2022 and may continue to spread to other European countries [3,21]. Climate change and human behaviour are creating ecological conditions that are more favourable for these *Aedes* species to breed, and the incidence of West Nile virus and dengue has increased dramatically in the EU since 2010. In 2013, 114 regions in 8 countries were affected by *Aedes albopictus*. In 2023, the mosquito is well established in 13 countries and 337 regions [3]. In 2022, active transmission of West Nile Virus was demonstrated in Italy, Greece, Romania, Germany, Hungary, Croatia, Austria, France, Spain, Slovakia and Bulgaria. Altogether 1,133 human cases and 92 deaths of West Nile virus infection were reported, and 1, 112 were locally acquired in the 11 countries with active transmission. The number of locally acquired dengue cases in 2022 was the same as the 71 reported between 2010 and 2021. Active transmission of dengue was demonstrated in France and Spain [3]. In the Americas, the 1.9 million dengue cases reported during the first five months of 2023 were more than the total reported for the region for the whole of 2021 and projected to surpass the 2.8 million registered in 2022 [10].

Dengue outbreaks have also been reported in countries in Africa. According to a statement by the government of Burkina Faso, released on 19 October and reported by the Reuters News Agency [22], dengue fever has killed 214 people in Burkina Faso since January 1, 2023, mainly in the two largest cities of Ouagadougou and Bobo-Dioulasso. There were 48 deaths reported from 9-15 October 2023 when the dengue epidemic coincided with an incidence of chikungunya.

Zika virus disease is also being reported from new geographical regions. Since 2019, two more countries (France and Kenya) were added to the list of countries with evidence of autochthonous, mosquito-borne transmission [23,24]. An outbreak was reported from the southern Indian state of Kerala in May 2021, which was the first report of Zika virus disease in WHO south east region after the outbreak in the Northern Indian states of Rajasthan and Madhya Pradesh in 2018 [7].

The movement of *Anopheles* mosquitoes across continents has hampered the recent progress against malaria in many countries in Africa. The main vectors of malaria in Africa are members of the *Anopheles gambiae* complex, including *Anopheles arabiensis, Anopheles coluzzii* and *Anopheles gambiae*, and *Anopheles funestus* vivax parasites to humans [25]. One threat to continued progress against malaria in Africa is the expansion of vectors into new areas. The South Asian vector, *Anopheles stephensi*, first reported in Djibouti in 2012 and recently discovered in Ethiopia, Ghana, Kenya, Nigeria, Sudan, Somalia and Somaliland [13-15,26], is raising concerns about enhanced transmission of malaria in urban areas in Africa. It is an important vector of urban malaria in South Asia and the Middle East, including the Arabian Peninsula and northwards across southern China [25]. *Anopheles stephensi* is well adapted to both rural and urban environments and breeds in various freshwater sources, including stagnant water bodies, rice fields, and water storage containers. It is a night-time feeder, primarily biting during the evening and night. It is known for its preference for biting humans and is considered an endophagic species, meaning it tends to rest indoors after feeding [11].

Malaria cases are also on the rise in Europe. In 2021, the European Union (EU) reported 4,856 malaria cases, with the majority being travel-related, but there were also 13 confirmed cases acquired within the EU (four in Greece and nine in France). A marked seasonal trend was observed across all countries, with cases increasing during and immediately after the summer holiday months (July–September), most likely reflecting travel patterns to malaria-endemic countries [5].

The US Centers for Disease Control and Prevention is warning of locally acquired malaria cases in the United States, with concerns that malaria could become more common as temperatures rise [2]. A recent study on climate change and malaria in Africa revealed a declining trend in malaria incidence rates from 2000 to 2018. However, these rates varied significantly, with high values in Uganda, Mozambique, Nigeria, and Zambia, and the vulnerability and changing climate may reverse the recent decline [27].

Vector control has played a more substantial role in reducing the prevalence of many mosquito-borne diseases compared to pharmaceuticals or vaccines [28]. However, the efficacy of vector control approaches is jeopardized by insecticide resistance, environmental concerns and the difficulties associated with manufacturing insecticidal materials in affected regions [29]. To address these challenges, scientists should employ modern molecular tools to enhance our understanding of vectors, their relationships with parasites, and insecticide resistance in affected areas. Regrettably, major funding organizations supporting research and capacity development in developing countries, such as the European and Developing Countries Clinical Trials Partnership, do not allocate resources to vector research [30].

Developing research capabilities in vector biology and control is crucial to comprehend and monitor the changing patterns of mosquito-borne diseases. This is essential for addressing the challenges arising from the influence of climate change on vector behaviour and the transmission of diseases such as chikungunya, dengue, malaria, yellow fever, and Zika. In resource-limited settings, there is an urgent need to strengthen national capacities and capabilities to respond to the emergence and re-emergence of vector-borne diseases with epidemic potential. In Sierra Leone, the Integrated Disease Surveillance and Response (IDSR) tool, a comprehensive, evidence-based strategy developed by the World Health Organization (WHO) for enhancing the effectiveness of national public health surveillance and response systems, has been used to monitor the long-term trend and seasonal variation in malaria [31].

We have demonstrated that climate change substantially affects the spread of vector-borne diseases. Many mosquito vectors of infectious diseases are already spreading across continents, aided by global trade and travel, and establishing in new areas previously unaffected by diseases like dengue and malaria. Changes at regional and national levels should be context- and disease-specific. To prevent the spread of vector-borne diseases, capacity enhancement is urgently needed in vector control and disease monitoring strategies. As of 3 December 2023, governments and development partners that participated in the COP28 Health Day had committed about US$ 1 billion to support knowledge generation, innovative financing, country capacity building, strategic partnerships, incubating innovations, and high-level advocacy on climate change and health [9].

Author declarations

The authors declare no conflicts of interest. The views expressed are those of the authors and not necessarily those of their respective institutions.

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References

[1] Wong C. Climate change is also a health crisis - these 3 graphics explain why. *Nature* 2023;**624**(7990):14–15.
[2] (CDC) CfDCaP-U. Locally Acquired Malaria Cases Identified in the United States. 2023 (https://emergency.cdc.gov/han/2023/han00494.asp Last accessed 11 December 2023).
[3] (ECDC) ECfDPaC. Dengue worldwide overview: European 2023; www.ecdc.europa.eu/en/dengue-monthly. Last accessed 12 December 2023.
[4] (ECDC) ECfDPaC. Chikungunya worldwide overview. 2023 (https://www.ecdc.europa.eu/en/chikungunya-monthly last accessed 12 December 2023).
[5] (ECDC) ECfDPaC. Malaria - Annual Epidemiological Report for 2021. 2023 (https://www.ecdc.europa.eu/en/publications-data/malaria-annual-epidemiological-report-2021 Last accessed 12 December 2023).
[6] Alied M, Endo PT, Aquino VH, Vadduri VV, Huy NT. Latin America in the clutches of an old foe: Dengue. *Braz J Infect Dis* 2023;**27**(4):102788.
[7] Akhtar N, Gupta SK, Singh H. Surveillance of Zika and Dengue viruses in field--collected Aedes aegypti mosquitoes from different states of India. *Virology* 2022;**574**:96–101.
[8] WHO. Climate change and health. 2023 (https://www.paho.org/en/topics/climate-change-and-health Last accessed 12 December 2023).
[9] (Editorial) LHealth Day at COP28: a hard-won (partial) gain. *Lancet* 2023;**402**(10418):2167.
[10] (Editorial) LDengue emergency in the Americas: time for a new continental eradication plan. *Lancet Reg Health Am* 2023;**22**:100539.
[11] Dalpadado R, Amarasinghe D, Gunathilaka N, Ariyarathna N. Bionomic aspects of dengue vectors Aedes aegypti and Aedes albopictus at domestic settings in urban, suburban and rural areas in Gampaha District, Western Province of Sri Lanka. *Parasit Vectors* 2022;**15**(1):148.
[12] Tatem AJ, Hay SI, Rogers DJ. Global traffic and disease vector dispersal. *Proc Natl Acad Sci U S A.* 2006;**103**(16):6242–7.
[13] Ahn J, Sinka M, Irish S, Zohdy S. Modeling marine cargo traffic to identify countries in Africa with greatest risk of invasion by Anopheles stephensi. *Sci Rep* 2023;**13**(1):876.
[14] KEMRI. Evidence Brief: Anopheles stephensi in Kenya. https://kemrigoke/wp-content/uploads/2023/02/Evidence-Brief-Anopheles-stephensi-in-Kenya-potentially-substantial-threat-to-malaria-transmission-in-urban-and-rural-areaspdf. 2023.
[15] Anonymous. Ghana reports presence of new mosquito, Anopheles stephensi. Outbreak News Today https://outbreaknewstodaycom/ghana-reports-presence-of-new-mosquito-anopheles-stephensi-74633/. 2023; Last accessed 11 December 2023.
[16] Urmi TJ, Mosharrafa RA, Hossain MJ, Rahman MS, Kadir MF, Islam MR. Frequent outbreaks of dengue fever in South Asian countries-A correspondence analyzing causative factors and ways to avert. *Health Sci Rep* 2023;**6**(10):e1598.
[17] Lenharo M. Dengue is breaking records in the Americas - what's behind the surge? *Nature* 2023.
[18] Coatsworth H, Lippi CA, Vasquez C, Ayers JB, Stephenson CJ, Waits C, et al. A molecular surveillance-guided vector control response to concurrent dengue and West Nile virus outbreaks in a COVID-19 hotspot of Florida. *Lancet Reg Health Am* 2022;**11**:100231.
[19] Burki T. Bangladesh faces record dengue outbreak. *Lancet* 2023;**402**(10400):439.
[20] Haider N, Asaduzzaman M, Hasan MN, Rahman M, Sharif AR, Ashrafi SAA, et al. Bangladesh's 2023 Dengue outbreak - age/gender-related disparity in morbidity and mortality and geographic variability of epidemic burdens. *Int J Infect Dis* 2023;**136**:1–4.
[21] Guzzetta G, Vairo F, Mammone A, Lanini S, Poletti P, Manica M, et al. Spatial modes for transmission of chikungunya virus during a large chikungunya outbreak in Italy: a modeling analysis. *BMC Med* 2020;**18**(1):226.
[22] Reuters. Dengue fever kills hundreds in Burkina Faso as cases spike. https://www.reuterscom/world/africa/dengue-fever-kills-hundreds-burkina-faso-cases-spike-2023-10-19/ Last accessed 21 October 2023. 2023.
[23] Salinas S, Simonin Y, L'Ambert G, Nisole S. [Autochthonous cases of Zika virus in metropolitan France: a new paradigm for this arbovirus?]. *Virologie (Montrouge)* 2019;**23**(6):329–32.
[24] Osoro E, Inwani I, Mugo C, Hunsperger E, Verani JR, Omballa V, et al. Prevalence of microcephaly and Zika virus infection in a pregnancy cohort in Kenya, 2017-2019. *BMC Med* 2022;**20**(1):291.
[25] Sinka ME, Pironon S, Massey NC, Longbottom J, Hemingway J, Moyes CL, et al. A new malaria vector in Africa: Predicting the expansion range of Anopheles stephensi and identifying the urban populations at risk. *Proc Natl Acad Sci U S A* 2020;**117**(40):24900–8.
[26] Allan R, Weetman D, Sauskojus H, Budge S, Hawail TB, Baheshm Y. Confirmation of the presence of Anopheles stephensi among internally displaced people's camps and host communities in Aden city. *Yemen. Malar J.* 2023;**22**(1):1.
[27] Leal Filho W, May J, May M, Nagy GJ. Climate change and malaria: some recent trends of malaria incidence rates and average annual temperature in selected sub-Saharan African countries from 2000 to 2018. *Malar J* 2023;**22**(1):248.
[28] Thomson MC, Stanberry LR. Climate Change and Vectorborne Diseases. *N Engl J Med* 2022;**387**(21):1969–78.
[29] Kouadio FA, Wipf NC, Nygble AS, Fodjo BK, Sadia CG, Vontas J, et al. Relationship between insecticide resistance profiles in Anopheles gambiae sensu lato and agricultural practices in Cote d'Ivoire. *Parasit Vectors* 2023;**16**(1):270.
[30] Nyirenda T, Bockarie M, Machingaidze S, Nderu M, Singh M, Fakier N, et al. Strengthening capacity for clinical research in sub-Saharan Africa: partnerships and networks. *Int J Infect Dis* 2021;**110**:54–61.
[31] George AM, Kargbou A, Wadsworth R, Kangbai JB. Trends and Seasonal Variations for Confirmed Malaria Cases for Sierra Leone for 2012 –2020. *SM Journal of Public Health & Epidemiology* 2023;**6**(4):1–4.