Climate change and the resurgence of waterborne diseases:

Focus on Sub-Saharan Africa

Sandy Moore, Infectious Disease Epidemiology Consultant, PhD
Rita Colwell, Environmental microbiologist, Distinguished University Professor at University of Maryland

Sandy Moore and Rita Colwell co-authored this article. Dr Moore is recognized for her work integrating epidemiological and phylogenic studies to establish a comprehensive understanding of cholera dynamics in Sub-Saharan Africa. Dr Colwell, a distinguished microbiologist, has pioneered research on global infectious diseases, marine bacteria and ecology. Their efforts have significantly advanced global health initiatives as well as disease prevention and control strategies.

Climate change, driven primarily by human activities, leads to persistent shifts in global temperatures and weather patterns. These changes trigger more frequent and intense weather events, which impact populations through both direct and indirect consequences. In particular, populations in Sub-Saharan Africa face heightened risks from climate change due in part to inadequate infrastructure and limited climate resilience. Climate change has significant implications for waterborne diseases, such as cholera, typhoid fever, schistosomiasis and hepatitis A, which affect populations throughout Sub-Saharan Africa. Limited access to clean water, sanitation, and hygiene infrastructure constitute significant risk factors for such diseases. Extreme climate-related events exacerbate these risks. For example, flooding can lead to contaminated water sources, while droughts compromise water quantity and quality. Additionally, extreme weather events can cause malnutrition, population displacement and disrupt livelihoods, further increasing vulnerability to diseases. Mitigating climate change involves reducing greenhouse gas emissions and transitioning to cleaner energy sources. However, short- to medium-term prevention and preparedness can minimize the impacts of waterborne diseases. To prevent waterborne diseases in Sub-Saharan Africa, it is crucial to improve access to safe drinking water, sanitation and hygiene infrastructure.

INTRODUCTION

Climate change refers to the persistent shifts in global temperatures and weather patterns. Although some of these changes are due to natural processes, human activities have become the predominant drivers. Climate change triggers extreme weather events, which are projected to become more frequent and intense, affecting certain regions of the globe more than others.

Beyond the significant environmental concerns posed by climate change, the impacts of these extreme weather events have far-reaching consequences on human health, especially for vulnerable populations. In many countries across Sub-Saharan Africa, extreme weather can adversely affect populations via both direct effects (e.g., infectious diseases, injury and fatalities) and indirect effects (e.g., chronic diseases, poor mental health, malnutrition, population displacement and reduced healthcare access). Moreover, the economic impacts of these natural disasters exacerbate population vulnerabilities, while constraining public health capacity to prevent and respond to health threats.

THE LINK BETWEEN CLIMATE CHANGE AND WATERBORNE DISEASES

Climate change has significant implications for waterborne diseases in Sub-Saharan Africa. These diseases are caused by pathogens such as viruses, parasites and bacteria, which can contaminate drinking water, food and water bodies. Major waterborne diseases that affect populations include cholera, typhoid fever, schistosomiasis, hepatitis A and poliomyelitis. Depending on the pathogen, disease transmission occurs through direct contact with infested water (e.g., bathing, washing, swimming) or via the fecal-oral route (ingesting water or food contaminated by the feces of infected individuals). Limited access to safe and clean water, sanitation and hygiene (WASH) infrastructure, along with open defecation, constitute significant risk factors. Climate change further heightens the risk of waterborne diseases by impacting WASH factors through increased precipitation, flooding, rising temperatures and drought.[1]

> *"Increased temperatures have shown significant positive association with waterborne diseases, caused by bacterial and protozoan pathogens. Warmer temperatures promote pathogen growth and reproduction."*

Bacteria seen under the microscope

Flooding events can augment the risk of waterborne disease outbreaks by contaminating drinking water sources and increasing human exposure to pathogens, especially in areas with inadequate WASH infrastructure. During extreme rainfall, sewer systems and latrines can overflow, discharging wastewater into the environment. In areas where open defecation is common, feces can contaminate surface water, which then infiltrates unprotected drinking water sources, damaged water distribution pipes, and water bodies used for recreational and domestic purposes. The concentration of waterborne pathogens in runoff tends to be higher in crowded urban settings or if a flooding event is preceded by a protracted dry period. Flooding can also hinder efforts to respond to infectious disease outbreaks.[2]

Increased temperatures have shown significant positive association with waterborne diseases caused by bacterial and protozoan pathogens. Warmer temperatures promote pathogen growth and reproduction. Rising ocean temperatures accelerate marine bacteria replication, resulting in bacterial blooms in coastal waters. Elevated environmental temperatures can also trigger expression of bacterial virulence genes in human pathogens, such as *Shigella* species.

Drought-induced water scarcity compromises both water quantity and quality. During prolonged droughts, people are forced to modify their behavior to secure access to drinking water, potentially jeopardizing their health. They may rely on contaminated water sources and store domestic water under inadequate conditions or use the same water source for multiple purposes (watering livestock, washing, cooking and drinking), risking additional contamination. People may also practice unsafe hygiene behaviors, such as reduced handwashing. The lack of clean water for consumption and hand hygiene increases the risk of contracting waterborne diseases. Indeed, in low- and middle-income countries, drought was found to be associated with a 5% to 8% increase in the risk of diarrhea among children under five. The association was stronger for households that had no access to water or soap for handwashing.[3]

Extreme weather events can also have serious indirect effects, such as malnutrition, population displacement and disrupted livelihoods. Loss of crops and livestock deaths due to flooding or drought contribute to famine and malnutrition, which in turn, weakens immune function. Severe, frequent or long-term natural disasters can also cause forced population displacement, a driving factor in spreading infectious diseases to new areas. Disruption of rural livelihoods can also accelerate the expansion of informal urban settlements, where access to safe water sources is often limited.

1 Semenza, J. C., & Ko, A. I. (2023). Waterborne diseases that are sensitive to climate variability and climate change. The New England Journal of Medicine, 389(23), 2175–2187. https://doi.org/10.1056/NEJMra2303681.

2 Semenza, J. C. (2020). Cascading risks of waterborne diseases from climate change. Nature Immunology, 21(5), 484–487. https://doi.org/10.1038/s41590-020-0648-9.

3 Wang, P., Asare, E., Pitzer, V. E., Dubrow, R., & Chen, K. (2022). Associations between long-term drought and diarrhea among children under five in low- and middle-income countries. Nature Communications, 13(1), 3661. https://doi.org/10.1038/s41467-022-31230-7.

CASE STUDY: CHOLERA

Cholera is an acute diarrheal disease caused by the bacterium *Vibrio cholerae*, which provokes severe diarrhea and dehydration and can lead to death within hours if untreated. The disease is generally contracted by ingesting water or food contaminated with toxigenic forms of *Vibrio cholerae* O1 and O139. Major factors of cholera transmission include limited access to safe drinking water and sanitation facilities. From 2017 to 2020, approximately 645,000 suspected cholera cases were reported in Africa.[4] Although the majority of African countries reported cholera cases during this time, the disease burden exhibited spatial heterogeneity, with certain regions regularly bearing the brunt of cholera epidemics.

"Poor access to WASH infrastructure and low sanitation access significantly contribute to cholera outbreaks."

CHOLERA EPIDEMICS DRIVEN BY DROUGHT IN THE HORN OF AFRICA

One of the major cholera hotspots on the continent is the Horn of Africa, most notably Somalia and Ethiopia. Poor access to WASH infrastructure (less than 60% of Somalians and Ethiopians have access to at least basic drinking water sources) and low sanitation access significantly contribute to cholera outbreaks. The Horn of Africa is also extremely vulnerable to climate-related risks, with frequent severe weather events including floods, rising temperatures and droughts.

Climate refugee migration - Somali families leave their homes due to deadly droughts and settle in refugee camps

A severe drought in late 2016 to 2017 increased water scarcity in this desert and semi-arid climate region. Against the backdrop of the drought, Somalia and Ethiopia experienced large-scale cholera epidemics. In 2017, Somalia reported a total of 75,414 suspected cases, a near five-fold increase in cholera cases compared with the previous year. At the time, WHO epidemiologists linked this surge to the drought which created widespread shortages of safe drinking water and food.

That same year, neighboring Ethiopia reported a total of 47,542 suspected cholera cases. Approximately 75% of all reported cases in Ethiopia were concentrated in Somali Region, which shares a border with the country of Somalia.[5] Pastoralist[6] communities in this desert region were forced to travel longer distances in search of water and gathered at unprotected water sources. As cholera affected pastoralists living in remote camps, access to healthcare was limited and a rapid response to control the outbreak was a significant challenge. Although direct evidence of cross-border transmission between Ethiopia and Somalia is limited, these two epidemics likely represent a single regional epidemic, with transborder transmission driven by population movement.

Climate change models have predicted further extreme dryness and drought not only in the Horn of Africa, but also in other areas such as the Sahel and southern Africa. These climate pattern projections indicate serious implications for the health of populations in drought-prone areas.

Cholera outbreaks triggered by cyclones in Mozambique

Mozambique represents another major cholera hotspot in Sub-Saharan Africa. From 2017 to 2022, Mozambique experienced cholera epidemics every year, with a total of 27,049 suspected cholera cases reported.[7] The country also has low WASH indicators and is susceptible to extreme climate events such as drought, storms and flooding.

In March of 2019, Cyclone Idai struck Mozambique. The storm made landfall twice, first as a tropical depression in Zambezia Province and second as a tropical cyclone near Beira City, Sofala Province. The cyclone caused torrential rains and winds. Crossing over land, the storm caused severe flooding that affected approximately 3 million people in Mozambique and neighboring countries.[8] In Mozambique alone, an estimated 1.85 million people were affected, with 603 deaths.[9] Thousands of houses were destroyed, which caused displacement of 400,000 people, primarily in shelters with poor access to basic water and sanitation services. Critical infrastructure such as roads, water supply, the electric grid, communication services, and healthcare centers suffered significant destruction, which hindered healthcare and response efforts.

4 World Health Organization. (2023). Cholera data 2000-2022 [Internet]. World Health Organization.

5 Moore, S., Worku Demlie, Y., Muluneh, D., Dunoyer, J., Hussen, M., Wossen, M., Edosa, M., & Sudre, B. (2024). Spatiotemporal dynamics of cholera epidemics in Ethiopia: 2015-2021. Scientific Reports, 14(1), 7170. https://doi.org/10.1038/s41598-024-51324-z:contentReference[oaicite:0]{index=0}.

6 Pastoralists are semi-nomadic or nomadic groups of people whose livelihood primarily depends on herding livestock.

7 World Health Organization. (2023). Cholera data 2000-2022 [Internet]. World Health Organization.

8 OCHA. (2019, March). Southern Africa: Cyclone Idai snapshot (as of 26 March 2019) [Data set]. https://www.medbox.org.

9 Government of Mozambique & World Health Organization. (2019, May 10). Tropical cyclones Idai and Kenneth, Mozambique National Situation Report 1. ReliefWeb. Retrieved from https://reliefweb.int/report/mozambique/tropical-cyclones-idai-and-kenneth-mozambique-national-situation-report-1-10-may.

In the areas severely affected by the cyclone, overcrowding, limited access to sanitation, as well as flooding that led to latrine overflow and contamination of the drinking water supply created ideal conditions for a waterborne disease outbreak. Only two weeks after Cyclone Idai made landfall near Beira—the region of Mozambique hardest hit by the cyclone – five cases of cholera were confirmed in Beira City. Thereafter, the cholera outbreak rapidly amplified, with 1,428 suspected cholera cases reported during the first week. Between March 27 and April 18, 2019, a total of 6,382 suspected cholera cases were reported.[10]

CASE STUDY: SCHISTOSOMIASIS

Schistosomiasis is an acute and chronic parasitic disease caused by trematode flatworms of the genus *Schistosoma*. Humans contract the disease in infested water, when larval forms of the parasite are released by freshwater snails and burrow into the host's skin. The parasite's lifecycle continues when people suffering from schistosomiasis contaminate freshwater sources with feces or urine containing parasite eggs. Schistosomiasis manifests in two major forms: intestinal and urogenital. Depending on the form, symptoms can include rash and fever, followed by abdominal pain, diarrhea, blood in the stool or urine, enlargement of the liver or spleen, and kidney or bladder damage. Schistosomiasis can cause anemia and stunting in children, thereby affecting development. The disease is prevalent among poor communities with limited WASH access located in tropical and subtropical regions and has been identified as one of the most widespread neglected tropical diseases in Sub-Saharan Africa. An estimated 112 million individuals are infected with *Schistosoma haematobium*, one of the most prevalent species of *Schistosoma* in Sub-Saharan Africa.[11]

> *"Climate change further compounds the level of vulnerability of these communities, as they lack the resources to adapt to extreme weather events."*

Climate change significantly influences schistosomiasis transmission in Africa by affecting the ecosystem and the lifecycle of freshwater snails and schistosomes. Extreme climate events can also alter human behaviors that contribute to the likelihood of exposure to infected snails.

Schistosomiasis transmission is temperature-dependent, affecting both parasite development and snail populations. A study has shown that between 15°C and 31°C, snail populations were stable and parasite production within snails was enhanced, thereby increasing metabolic activity and vitality. However, beyond these temperatures snail numbers sharply declined.[12] Infection risk may rise with small temperature increases in regions characterized by this ideal temperature range, while it may decrease in hotter regions, depending on the local species of host snail. For example, a study in Zimbabwe showed a downward trend in schistosomiasis prevalence from 1981 to 2010, in parallel with a transition towards a warmer and drier climate.[13]

Increased rainfall plays a significant role in schistosomiasis transmission throughout Sub-Saharan Africa. In Ghana, increased precipitation levels have been positively correlated with schistosomiasis prevalence, while years with reduced rainfall have shown a negative correlation.[14] Increased rainfall creates additional suitable habitats for snails, allowing populations to expand. When the levels of waterbodies rise, people may come into contact with infested water more frequently. However, during severe storms, rainfall may have a negative impact on transmission when snail habitats become disrupted by fast flowing waters.

Drought impacts schistosomiasis transmission. In Ethiopia, prolonged drought resulted in reduced prevalence of schistosomiasis due to a decrease in both transmission sites and the reproductive and survival rates of the intermediate host snails.[15] However, in Senegal, shorter drought periods were associated with an increased risk of schistosomiasis transmission.[16] These variations likely also depend on location, climate and intermediate host species.

Overall, as the impact of climate change on snail populations and parasites is complex and can either increase or decrease the risk of schistosomiasis depending on the context, the future trajectory of the disease is challenging to forecast.

VULNERABLE POPULATIONS

In Africa, waterborne diseases disproportionately affect low-income areas with inadequate access to WASH services and healthcare. Climate change further compounds the level of vulnerability of these communities, as they lack the resources to adapt to extreme weather events. In Sub-Saharan Africa, 65% of the population has access to at least basic drinking water services, while 37% of the population has access to at least basic sanitation infrastructure. However, there are significant variations across the continent. Countries with low average drinking water coverage rates between 35% and 60% include the Democratic Republic of Congo (DRC), Central African Republic, South Sudan, Niger, Ethiopia and Somalia.[17]

10 Lequechane, J. D., et al. (2020). Mozambique's response to cyclone Idai: How collaboration and surveillance with water, sanitation and hygiene (WASH) interventions were used to control a cholera epidemic. Infectious Diseases of Poverty, 9(68). https://doi.org/10.1186/s40249-020-00673-7.

11 World Health Organization. (2020). Current estimated total number of individuals with morbidity and mortality due to Schistosomiasis haematobium and S. mansoni infection in Sub-Saharan Africa. World Health Organization. Retrieved from https://www.who.int/schistosomiasis/epidemiology/en/.

12 McCreesh, N., & Booth, M. (2014). The effect of simulating different intermediate host snail species on the link between water temperature and schistosomiasis risk. PLoS ONE, 9(7), e87892. https://doi.org/10.1371/journal.pone.0087892.

13 Pedersen, U. B., et al. (2017). Comparison of the spatial patterns of schistosomiasis in Zimbabwe at two points in time, spaced twenty-nine years apart: Is climate variability of importance? Geospatial Health, 12(1), 505. https://doi.org/10.4081/gh.2017.505.

14 Codjoe, S. N. A., & Larbi, R. T. (2016). Climate change/variability and schistosomiasis transmission in Ga district, Ghana. Climate and Development, 8(1), 58–71. https://doi.org/10.1080/17565529.2015.1008771.

15 Zein, Z. A. (1989). Spontaneous reduction in Schistosoma mansoni infection in endemic communities of the Lake Tana basin, north-western Ethiopia. Transactions of the Royal Society of Tropical Medicine and Hygiene, 83(5), 656–658. https://doi.org/10.1016/0035-9203(89)90209-0&#8203.

16 Senghor, B., Diaw, O. T., Doucoure, S., Sylla, S. N., Seye, M., & Talla, I. (2015). Study of the snail intermediate hosts of urogenital schistosomiasis in Niakhar, region of Fatick, West central Senegal. Parasites & Vectors, 8, 410. https://doi.org/10.1186/s13071-015-1050-6.

17 WHO, & UNICEF. (2023). Progress on drinking water, sanitation and hygiene: 2023 update and SDG baselines. Joint Monitoring Programme (JMP). https://data.unicef.org/resources/jmp-report-2023/.

These figures are concretely reflected in the expansion of waterborne diseases, highlighting the importance of having not only access to drinking water but also to WASH services. Indeed, four of these countries (DRC, Somalia, Ethiopia and Niger) reported nearly 40% of all suspected cholera cases in Africa from 2019 to 2022.

Many populated urban areas with informal urban settlements are often characterized by inadequate sewage, unsafe piped water networks, and dysfunctional rainwater drainage systems, subjecting residents to a high risk of contracting waterborne diseases, especially during the rainy season. Indeed, cholera outbreaks have been shown to amplify exponentially in urban settings, as observed in Accra, Conakry, Nairobi, Port-au-Prince, and many other cities. Other populations that are particularly at risk include refugees, internally displaced persons, nomadic populations and other marginalized groups with limited access to WASH services and healthcare. Remote and hard-to-reach populations are also vulnerable to waterborne diseases, as healthcare access is limited for these communities and outbreak response measures are often delayed.

PUBLIC HEALTH RESPONSE

Mitigating climate change involves reducing greenhouse gas emissions by transitioning away from fossil fuels towards cleaner energy sources, reforestation, and sustainable practices. However, short- to medium-term prevention, preparedness and response interventions can significantly minimize the impacts of waterborne diseases due to climate change.

Boosting climate resilience to **prevent waterborne diseases** involves a multi-faceted approach (e.g., community engagement, policy, research and innovation). A key strategy focuses on reducing the underlying vulnerabilities by improving access to safe drinking water and effective sanitation. For example, the Veolia Foundation supports cholera elimination efforts in the DRC by implementing sustainable and resilient WASH services, such as water network rehabilitation in cholera hotspots. Such preventative measures should be focused on areas where populations are at a high risk of waterborne diseases and prioritizing regions at risk of natural disasters. Epidemiological studies and risk assessments are critical to identify disease hotspots, highly exposed populations, and areas of converging risk factors.

Preparedness and response measures should be strengthened to control outbreaks when they occur, through strong coordination, multisectoral engagement, robust disease surveillance, early warning systems,[18 19] effective risk communication, community engagement, and proper case management. Vaccination against waterborne diseases such as cholera, hepatitis A and typhoid fever can be effective when appropriate and feasible. As soon as cases of waterborne diseases are detected, a rapid response guided by real-time surveillance data is critical to stop transmission and prevent avoidable deaths, especially for diseases with a short incubation period such as cholera. Recognizing interconnectedness between human health and the environment, One Health approaches that integrate weather and climate monitoring into early warning systems can help to quickly identify those areas at risk, triggering prompt preventive and response interventions.

CONCLUSION

Extreme weather events due to human-driven climate change have considerable implications for population health. In particular, many waterborne diseases pose a significant public health threat, especially in Sub-Saharan Africa. Limited access to safe drinking water and sanitation facilities are key risk factors for waterborne diseases. Severe weather phenomena play a significant role in the transmission dynamics of waterborne diseases by impacting access to safe water sources. Climate change can also compound health disparities, by hindering healthcare opportunities, causing malnutrition and restricting public health capacity. Thus, in areas with poor WASH indicators, extreme weather can rapidly escalate into a catastrophic public health emergency. Severe droughts, floods and storms have affected many regions across sub-Saharan Africa, and the intensity and frequency of these natural disasters will increase due to climate change, albeit in a heterogenous manner. As a result, many vulnerable populations will face heightened risk. To prevent waterborne diseases in Sub-Saharan Africa, it is critical to improve safe and equitable access to drinking water and sanitation, ideally by applying a holistic approach to building community resilience that can cope with the multifaceted effects of climate change.

18 Usmani, M., et al. (2024). Building environmental and sociological predictive intelligence to understand the seasonal threat of SARS-CoV-2 in human populations. American Journal of Tropical Medicine and Hygiene, 110(3), 518–528. https://doi.org/10.4269/ajtmh.23-0077.

19 Usmani, M., et al. (2023). Combating cholera by building predictive capabilities for pathogenic Vibrio cholerae in Yemen. Scientific Reports, 13, 2255. https://doi.org/10.1038/s41598-022-22946-y.