THE IMPACT OF CLIMATE CHANGE-DRIVEN HYDROLOGICAL DISASTERS ON HOSPITAL RESILIENCE

Mariya Georgieva
Department of Epidemiology and Disaster Medicine, Faculty of Public Health, Medical University of Plovdiv, Bulgaria, mari.georgieva@mu-plovdiv.bg
Rostislav Kostadinov
Department of Epidemiology and Disaster Medicine, Faculty of Public Health, Medical University of Plovdiv, Bulgaria, rostislav.kostadinov@mu-plovdiv.bg
Elena Valkanova
Department of Epidemiology and Disaster Medicine, Faculty of Public Health, Medical University of Plovdiv, Bulgaria, elena.valkanova@mu-plovdiv.bg

Abstract: The contemporary world is recording a steady increase in the frequency of hydrological disasters. Notwithstanding that most countries have declared their willingness to decrease harmful environmental emissions, the reality is that global warming is on a steady increase every year. The consequences are visible as newly higher temperature records worldwide and with unusual and prolonged floods and draughts. Climate change-induced hydrological disasters, such as floods pose significant challenges to the resilience of hospital infrastructure and healthcare delivery systems. These disasters have an extensive potential to disrupt hospital operations, overwhelm healthcare facilities, and exacerbate public health risks. This article aims to explore the ramifications of climate change-driven hydrological disasters on hospital resilience, employing an academic lens to analyze their possible negative implications. Descriptive and comparative methods were applied to analyze the available reports and group the recorded negative impact on static and operative hospital resilience due to climate change-driven hydrological disasters. There is consensus in the literature that climate change is amplifying the frequency and intensity of hydrological disasters worldwide, leading to more frequent and severe floods, heavy rains, and other water-related events. The altered precipitation patterns, rising sea levels, and increased temperatures associated with climate change contribute to the worsening of hydrological disasters, posing considerable threats to hospital infrastructure and operations. Hydrological disasters can have multifaceted impacts on hospital resilience. Some of the most frequently reported include: 1. Infrastructure Damage: Floodwaters and storm surges can cause structural damage to hospital buildings, disrupting essential services and compromising patient care. 2. Operational Disruptions: Power outages, supply chain disruptions, and transportation difficulties resulting from hydrological disasters can impede hospitals' ability to function effectively, leading to delays in patient treatment and evacuation challenges. 3. Increased Patient Load: Hydrological disasters often result in a surge of injured individuals seeking medical attention, overwhelming hospital capacity, and straining resources. 4. Health Risks: Floodwaters may introduce contaminants and pathogens into hospital premises, increasing the risk of waterborne diseases and infections among patients and healthcare workers. In conclusion, must be noted that climate change-driven hydrological disasters present a myriad of significant challenges to hospital resilience. Their negative impacts have the potential to severely jeopardize the healthcare provision to the population, necessitating proactive measures to enhance preparedness and mitigate risks.
Keywords: hospital disaster resilience, climate change, hydrological disasters, floods, health risks

1. INTRODUCTION

The contemporary world is recording a steady increase in the frequency of hydrological disasters. (1-3) Notwithstanding that most countries have declared their willingness to decrease harmful environmental emissions, the reality is that global warming is on a steady increase every year. Global warming, a key aspect of climate change, is abundantly evident in various aspects of the contemporary world, supported by a wealth of scientific evidence from multiple disciplines. Some of the most evident proofs of global warming observed in the contemporary world are listed:

- Temperature Records: One of the most compelling pieces of evidence for global warming is the observed increase in global average temperatures over time. Temperature records collected from weather stations, satellites, and ocean buoys consistently show a warming trend spanning several decades. The Intergovernmental Panel on Climate Change (IPCC) reports that each of the last four decades has been successively warmer than any decade that preceded it since 1850, with the most recent decade being the warmest on record.

- Rising Temperatures: In addition to long-term temperature trends, there is widespread evidence of rising temperatures across various regions of the world. Heatwaves have become more frequent, intense, and prolonged in many parts of the globe, leading to record-breaking high temperatures and increased heat-related health risks. Moreover, warming trends are particularly pronounced in polar regions, where temperatures are rising at a rate more than twice the global average, leading to rapid ice melt and changes in ecosystems.
- Glacier Retreat and Ice Loss: Observations of glacier retreat and ice loss provide further evidence of global warming. Glaciers and ice sheets around the world are shrinking at an accelerating rate, leading to rising sea levels and contributing to changes in regional hydrology and water availability. For example, the Greenland Ice Sheet has experienced significant melting in recent years, contributing to sea level rise and coastal flooding. Similarly, glaciers in mountainous regions such as the Himalayas and Andes are receding rapidly, impacting water resources for millions of people downstream.
- Sea Level Rise: Sea level rise is a direct consequence of global warming, driven primarily by thermal expansion of seawater and the melting of ice caps and glaciers. Satellite observations and tide gauge measurements indicate that sea levels have risen by approximately 20-23 centimeters since the late 19th century, with the rate of rise accelerating in recent decades. Rising sea levels pose significant threats to coastal communities, infrastructure, and ecosystems, exacerbating risks of flooding, erosion, and saltwater intrusion.
- Changes in Extreme Weather Events: Global warming is altering the frequency, intensity, and distribution of extreme weather events such as hurricanes, droughts, floods, and wildfires. Warmer temperatures fuel more intense and frequent heatwaves, while changes in atmospheric circulation patterns can lead to shifts in precipitation patterns and increased variability in weather conditions. For example, warmer oceans provide more energy to fuel tropical cyclones, leading to stronger storms and increased rainfall. Similarly, changes in atmospheric circulation patterns can prolong drought conditions in some regions while intensifying rainfall and flooding in others.
- Ocean Acidification and Coral Bleaching: The absorption of excess carbon dioxide (CO2) by the world's oceans is leading to ocean acidification, a process that has profound implications for marine ecosystems. Increased CO2 levels lower the pH of seawater, making it more acidic and threatening the health of coral reefs, shell-forming organisms, and marine food webs. Coral bleaching events, driven by elevated sea temperatures and stress from ocean acidification, have become more frequent and severe in recent decades, leading to widespread coral mortality and ecosystem degradation.
- Changes in Biological Systems: Global warming is disrupting ecosystems and altering the distribution and behavior of plant and animal species around the world. Species are shifting their ranges poleward or to higher elevations in response to changing temperature and climate conditions, leading to changes in species composition, phenology, and ecosystem dynamics. For example, Arctic ecosystems are experiencing rapid changes as warming temperatures alter sea ice extent, permafrost stability, and the timing of seasonal events such as migration and reproduction.
- Their consequences are visible as newly higher temperature records worldwide and with unusual and prolonged floods and draughts. (4, 5) Changes into climate that are recorded nowadays are one of the main triggers of the hydrological disasters reported almost all over the contemporary world. (6-15) Climate change-induced hydrological disasters, such as floods pose significant challenges to almost all aspects of our life. The resilience of hospital infrastructure and healthcare delivery systems are one of the most affected, as lifesaving and preserving the individual and population health are the main objectives of every disaster relief operation. These disasters have an extensive potential to disrupt hospital operations, overwhelm healthcare facilities, and exacerbate public health risks.
- This article aims to explore the ramifications of climate change-driven hydrological disasters on hospital resilience, employing an academic lens to analyze their possible negative implications.
- Descriptive and comparative methods were applied to analyze the available reports and group the recorded negative impact on static and operative hospital resilience due to climate change-driven hydrological disasters.

2. RESULTS AND DISCUSSIONS

There is consensus in the literature that climate change is amplifying the frequency and intensity of hydrological disasters worldwide, leading to more frequent and severe floods, heavy rains, and other water-related events. (11, 16) The altered precipitation patterns, rising sea levels, and increased temperatures associated with climate change

contribute to the worsening of hydrological disasters, posing considerable threats to hospital infrastructure and operations. Hydrological disasters can have multifaceted impacts on hospital resilience. Some of the most frequently reported include:

Infrastructure Damage: Floodwaters and storm surges can cause structural damage to hospital buildings, disrupting essential services and compromising patient care. Hydrological disasters, can have significant impacts on hospital infrastructure, compromising the ability of healthcare facilities to provide essential medical services to patients. These impacts vary depending on the severity of the disaster, the vulnerability of the hospital infrastructure, and the effectiveness of preparedness and mitigation measures. Some of the most important are related to the possible structural damage. Hydrological disasters, particularly floods, can cause extensive structural damage to hospital buildings and facilities. Floodwaters can inundate lower levels of buildings, leading to water damage, foundation instability, and structural collapse. Electrical and mechanical systems within hospitals can be often disrupted and lead to essential systems shortages, including power supply, heating, ventilation, and air conditioning (HVAC), and medical gas delivery systems. Floodwaters can damage electrical equipment, wiring, and control systems, leading to power outages and disruptions to critical life support systems, diagnostic equipment, and communication systems. HVAC systems may also be compromised, leading to indoor air quality issues, mold growth, and thermal discomfort for patients and staff.

Another structural damage could be the adverse effects on water supply and sanitation. Floods can compromise the water supply and sanitation infrastructure serving hospitals, leading to disruptions in water availability, quality, and sanitation. Contamination of water sources by floodwaters can render them unsafe for drinking, hygiene, and medical procedures, increasing the risk of waterborne diseases and infection transmission. Additionally, damage to sewage systems can result in sewage backups, foul odors, and environmental contamination within hospital facilities, posing health hazards to patients and staff.

Has to be noted the frequently reported impact on the medical infrastructure. Hydrological disasters can damage or destroy medical equipment, supplies, and pharmaceuticals stored within hospitals, compromising the ability to deliver essential medical services to patients. Floodwaters can inundate equipment storage areas, medical supply rooms, and pharmacies, leading to water damage, contamination, and loss of inventory. Moreover, exposure to moisture, temperature extremes, and contaminants can render medical equipment and supplies unusable, requiring costly replacement and restocking efforts.

One of the main challenges towards the hospital operability is the related to the impeded by the flooding access and egress. Hydrological disasters can disrupt access to and egress from hospital facilities, hindering the arrival of patients, staff, and emergency responders, as well as the evacuation of patients in need of urgent medical care. Flooded roadways, washed-out bridges, and debris blockages can impede transportation routes, delaying the arrival of ambulances, medical supplies, and relief personnel. Additionally, flooding within hospital facilities can obstruct corridors, stairwells, and exits, complicating evacuation efforts and increasing the risk of injury or loss of life. Floods could have direct impact on patient care areas within hospitals, including patient wards, emergency departments, operating theaters, and intensive care units. Floodwaters can inundate patient care areas, leading to evacuation, relocation, or closure of clinical spaces. Moreover, disruptions to electrical, mechanical, and water supply systems can compromise patient safety and quality of care, necessitating contingency plans for maintaining essential medical services and ensuring patient comfort and well-being.

Operational Disruptions: Power outages, supply chain disruptions, and transportation difficulties resulting from hydrological disasters are with direct negative impact on hospitals' ability to function effectively, leading to delays in patient treatment and evacuation challenges.

Results of the performed analyses of the published studies of the flooding hospital impact describe significant negative effects related to increased patients' admissions and elevated health risk for both hospital staff and patients. Floods significantly impact on both the patient load and health risks for hospital staff and patients. These impacts arise from a combination of direct effects of flooding on healthcare facilities, changes in patient demand, and increased health risks associated with flood-related hazards.

Floods often result in an influx of patients seeking medical care for flood-related injuries, illnesses, and exacerbation of pre-existing health conditions. Injuries such as cuts, abrasions, and fractures may occur due to contact with floodwaters, falls, or accidents during evacuation or cleanup efforts. Additionally, individuals with chronic health conditions, such as respiratory diseases, cardiovascular disorders, and mental health issues, may experience worsening symptoms or complications due to exposure to flood-related stressors and environmental hazards. These flood-related injuries and illnesses usually very rapidly overwhelm emergency departments (EDs), leading to overcrowding, prolonged wait times, and delays in care for patients with urgent medical needs. The sudden surge in patients' admissions may strain hospital resources, including medical staff, equipment, and treatment spaces, making it challenging to provide timely and effective care to all patients and the population in need. As a result, very often

floods may disrupt scheduled elective procedures and non-urgent medical services, as hospitals prioritize emergency and critical care in response to the increased demand for medical services. Cancelled or postponed procedures can result in patient inconvenience, treatment delays, and challenges in managing patient expectations and follow-up care.

3. CONCLUSION

It is highly probable that floodwaters can contain a variety of contaminants, including sewage, chemicals, pathogens, and debris, posing health risks to hospital staff and patients. Direct contact with contaminated water can lead to skin irritation, gastrointestinal illnesses, and infections. Moreover, inhalation of aerosolized contaminants or mold spores can exacerbate respiratory conditions and trigger allergic reactions among susceptible individuals. Another health risk is related to the in-hospital infection, because flood-related hazards such as standing water, sewage backups, and water-damaged building materials are creating ideal breeding grounds for bacteria, viruses, and mold, increasing the risk of infection transmission within hospital facilities. Nosocomial infections, including gastrointestinal infections, respiratory infections, and skin infections, may occur among patients and staff exposed to contaminated environments or inadequate infection control measures. Moreover, the prolonged exposure to damp indoor environments and water-damaged materials can promote mold growth within hospital facilities, leading to indoor air quality issues and health risks for patients and staff. Inhalation of mold spores can exacerbate asthma and allergies, trigger respiratory symptoms, and compromise immune function, particularly among immunocompromised individuals and patients with pre-existing respiratory conditions.

All these effects are with significant impact on the psychological stamina of the medical specialists and the patients and are with potential to induce psychological distress and mental health symptoms among hospital staff and patients, including anxiety, depression, post-traumatic stress disorder (PTSD), and acute stress reactions. Staff may experience feelings of overwhelm, burnout, and compassion fatigue due to the emotional toll of caring for flood-affected patients and working in challenging conditions. Patients, particularly those directly impacted by the flood, may experience heightened stress, fear, and uncertainty about their health, safety, and future well-being.

In conclusion, must be noted that climate change-driven hydrological disasters present a myriad of significant challenges to hospital resilience. Their negative impacts have the potential to severely jeopardize the healthcare provision to the population, necessitating proactive measures to enhance preparedness and mitigate risks.

REFERENCES

Alifu, H., Hirabayashi, Y., Imada, Y., & Shiogama, H. (2022). Enhancement of river flooding due to global warming. *Scientific Reports*, *12*(1), 20687.

Banda, V. D., Dzwairo, R. B., Singh, S. K., & Kanyerere, T. (2022). Hydrological modelling and climate adaptation under changing climate: a review with a focus in Sub-Saharan Africa. *Water*, *14*(24), 4031.

Brêda, J. P. L., de Paiva, R. C. D., Siqueira, V. A., & Collischonn, W. (2023). Assessing climate change impact on flood discharge in South America and the influence of its main drivers. *Journal of Hydrology*, *619*, 129284.

Clarke, B., Otto, F., Stuart-Smith, R., & Harrington, L. (2022). Extreme weather impacts of climate change: an attribution perspective. *Environmental Research: Climate*, *1*(1), 012001.

Hirabayashi, Y., Alifu, H., Yamazaki, D., Imada, Y., Shiogama, H., & Kimura, Y. (2021). Anthropogenic climate change has changed frequency of past flood during 2010-2013. *Progress in Earth and Planetary Science*, *8*(1), 1-9.

Jiang, R., et al. (2023). Substantial increase in future fluvial flood risk projected in China's major urban agglomerations. *Communications Earth & Environment*, *4*(1), 389.

Lu, L. C., Chiu, S. Y., Chiu, Y. H., & Chang, T. H. (2022). Sustainability efficiency of climate change and global disasters based on greenhouse gas emissions from the parallel production sectors–A modified dynamic parallel three-stage network DEA model. *Journal of Environmental Management*, *317*, 115401.

Noto, L. V., Cipolla, G., Francipane, A., & Pumo, D. (2023). Climate change in the mediterranean basin (part I): Induced alterations on climate forcings and hydrological processes. *Water Resources Management*, *37*(6), 2287-2305.

Parmesan, C., Morecroft, M. D., & Trisurat, Y. (2022). *Climate change 2022: Impacts, adaptation and vulnerability* (Doctoral dissertation, GIEC).

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., ... & Zhou, B. (2021). Weather and climate extreme events in a changing climate (Chapter 11).

Tabari, H., Hosseinzadehtalaei, P., Thiery, W., & Willems, P. (2021). Amplified drought and flood risk under future socioeconomic and climatic change. Earth's Future, 9(10), e2021EF002295.

Tabari, H. (2020). Climate change impact on flood and extreme precipitation increases with water availability. Sci Rep 10, 13768 https://doi.org/10.1038/s41598-020-70816-2

Tellman, B., et al. (2021). Satellite imaging reveals increased proportion of population exposed to floods. *Nature*, *596*(7870), 80-86.

Thompson, J. R., Gosling, S. N., Zaherpour, J., & Laizé, C. L. R. (2021). Increasing risk of ecological change to major rivers of the world with global warming. *Earth's Future*, *9*(11), e2021EF002048.

Wu, Y., Yin, X., Zhou, G. et al. (2024). Rising rainfall intensity induces spatially divergent hydrological changes within a large river basin. Nat Commun 15, 823. https://doi.org/10.1038/s41467-023-44562-8

Yang, P., Zhang, S., Xia, J., Zhan, C., Cai, W., Wang, W., ... & Li, J. (2022). Analysis of drought and flood alternation and its driving factors in the Yangtze River Basin under climate change. *Atmospheric Research*, *270*, 106087.