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Comprehensive Analysis of Health Impacts Arising from Flood Disasters: Evidence from Pakistan's Vulnerable Regions

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ABSTRACT

Climate change has resulted in progressively erratic environmental conditions, leading to significant health repercussions. On a global scale, inundations and extreme climatic events substantially contribute to escalating rates of morbidity and mortality annually. These calamities not only amplify fatality figures but also present considerable health challenges for those who survive. This research assesses the susceptibility and health ramifications associated with devastating flooding through the examination of injury, illness, and mortality trends. The method involved in this research was a literature based conducting 40 studies from different sources including Google scholar, Science Direct, Scopus and Websites online to find out the situations of health departments during floods and other weather conditions. The results underscore the significant repercussions of flooding on public health, encompassing immediate effects such as physical injuries, infections, and disruptions in healthcare provision. Flooding is often connected to a greater risk of disease outbreaks, comprising dengue fever, hepatitis E, conjunctivitis, leptospirosis, and digestive disorders, particularly impacting those who are displaced or dwell in unsanitary environments. Furthermore, investigations concludes that the physical health impacts resulting from flooding are heightened due to the psychological trauma and mental health struggles among those who endure it. To more effectively tackle the health ramifications of flooding, this research advocates for policy initiatives directed at enhancing the resilience and efficacy of existing flood response frameworks.

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Introduction

Climate change constitutes one of the most urgent global issues of our time, endangering the sustainability of ecosystems and the livelihoods of populations, particularly within rural sectors of developing countries (Khoso et al., 2024). It is well observed in Pakistan, that the climate change has been the major concern of increasing day by day consequence floods in

Indus River at greater extent and assembling more loss in recent years. Throughout the past decade, these floods have dramatically affected infrastructure and local communities (UNFPA, 2022). The ramifications of climate change are extensive, influencing food security, access to potable water, public health, ecosystems, and the livelihoods of both humans and wildlife, regardless of geographic location or socio-economic status (Shafi et al., 2022; Adams, 2009). Research findings robustly suggest that anthropogenic activities serve as a principal catalyst for the ongoing climate alterations, with specialists cautioning that certain changes may become irreversible, disproportionately impacting marginalized and vulnerable groups. Flooding, in particular, represents a severe threat to public health, resulting in fatalities and widespread social upheaval (Khushi et al., 2024; Ajani and Van, 2021; Huang et al., 2024; Khan et al., 2024). Moreover, political and institutional inefficiencies frequently exacerbate the health hazards encountered by affected communities, obstructing their capacity to adapt and recuperate from environmental crises (Rehman, 2022). The escalating frequency and intensity of extreme weather phenomena, combined with inadequate flood management strategies in urban planning, have intensified global apprehension regarding the risks associated with climate change. Floods caused either by heavy rains or streamflow of canals origins the natural disaster almost covering more than regions with specifically, social, political, economic, agricultural, infrastructure as well health concerns. (Khan, 2022). The Himalayan region, which contains substantial glacial resources, is particularly susceptible to increasing temperatures, endangering essential natural assets (Caney, 2012). Intense rainfall, often attributed to climate change, is the primary factor behind recurrent floods in this area, which constitute approximately 40% of all natural calamities (Shah et al., 2020). Vulnerable to climate change's consequences, Pakistan encounters several challenges like flash floods driven by quick glacial melting, increased monsoon rainfall, prolonged heatwaves, water scarcity, rising sea levels, food insecurity, and drought conditions, particularly in the southern area of Sindh. These occurrences are leading to significant population displacement. Furthermore, the nations antiquated land administration system, deeply entrenched in colonial legacies and devoid of meaningful reforms, has exacerbated urban development issues, thereby heightening susceptibility to environmental catastrophes (Baqir et al., 2012). Besides that, the rainfall at greater extent are considered to be the major aspect towards the negative health concerns including diarrhea, malaria, high fever and skin irritation specifically the under developing nations providing economic challenges to the communities. Climate change exacerbates these difficulties by inducing unpredictable variations in environmental conditions that negatively affect human health (Gardiner, 2004). Annually, floods result in disease outbreaks, increased mortality rates, and ongoing health risks for survivors. Given the widespread and destructive implications of flooding, it has emerged as a global issue necessitating coordinated international initiatives to alleviate its consequences. Tackling this pressing concern requires comprehensive assessment and strategic planning to mitigate the health impacts of flooding, especially as climate change continues to modify environmental dynamics. Collaborative efforts involving all stakeholders are imperative in addressing this escalating threat.

Literature Review

Flood damages and health risks from 2003 to 2022

Since its establishment, Pakistan has encountered a variety of natural calamities, including floods, earthquakes, windstorms, and droughts. These occurrences have resulted in considerable devastation to infrastructure, livelihoods, healthcare systems, education,

communication networks, and businesses (Mahesar, 2022). Being home to the largest number of glaciers outside the Polar Regions, Pakistan is especially vulnerable to flooding and other

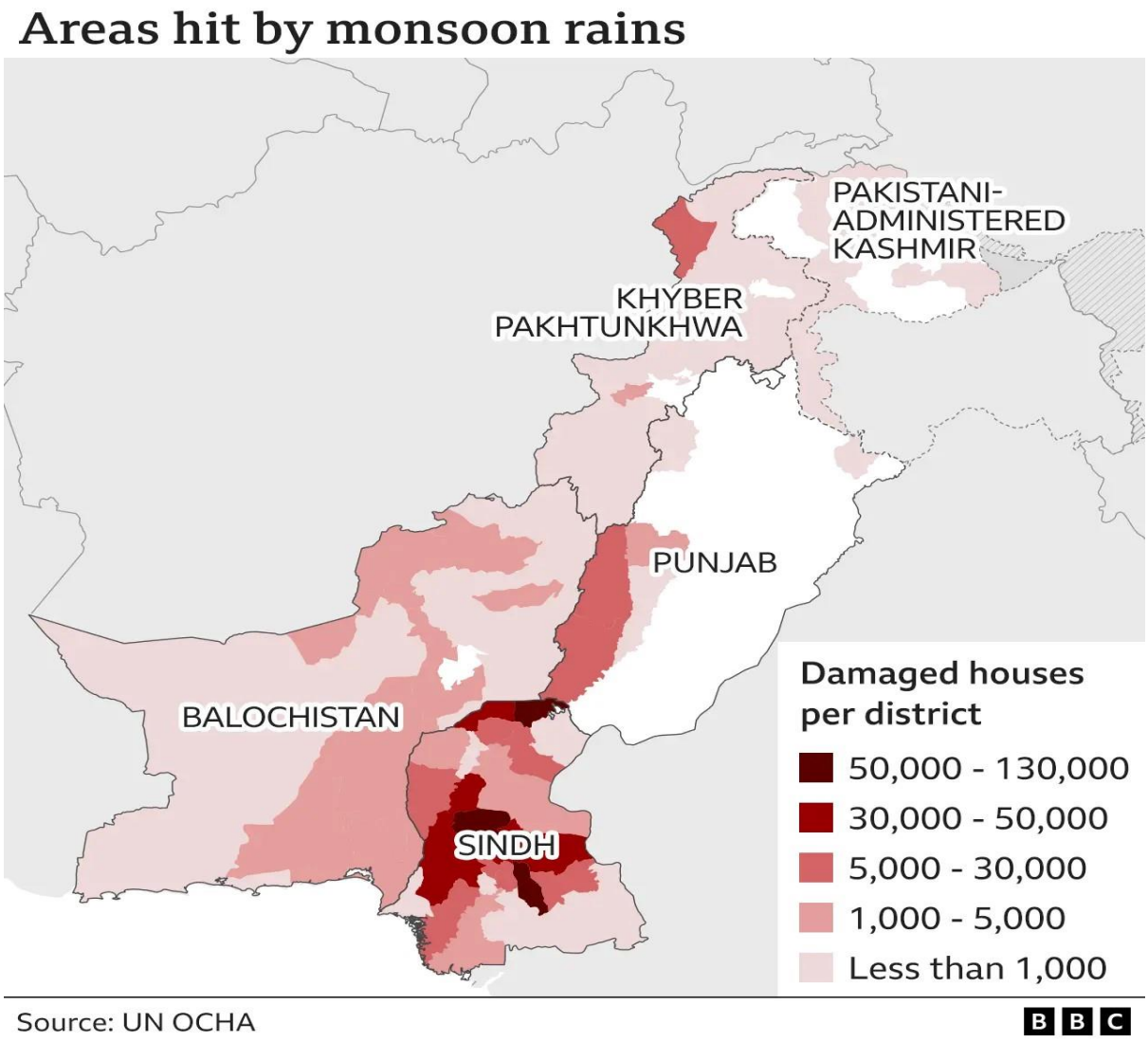


Fig-1: Area hit by the monsoon rains in Pakistan

water-related catastrophes as shown in fig-1. The monsoon season, intensified by climate change, amplifies socio-economic difficulties and has significant implications for public health.

Flooding remains a persistent challenge across multiple regions of Pakistan. For example, in 2003, excessive monsoon precipitation led to severe flooding in Sindh Province. Karachi faced urban flooding due to 284.5 mm of rain within a span of two days, resulting in widespread devastation. In Thatta District, 404 mm of rainfall instigated calamitous flash floods (The express tribune, 2004). These incidents resulted in 484 deaths and considerable damage across numerous municipalities within the province (Islamic Relief Worldwide, 2009; Monson, 2011). In a similar vein, in 2010, unprecedented rainfall in Khyber Pakhtunkhwa and Punjab triggered disastrous flooding throughout the country. This calamity impacted approximately 20 million individuals, leading to over 2,000 fatalities (Pakistan Flood, 2010). Although the immediate death toll was relatively modest, the long-term health

repercussions were severe, with 77% of households indicating injuries or illnesses associated with the flooding (Kirsch et al., 2012). The subsequent floods in 2011 and 2012 resulted in extensive devastation in Sindh, Punjab, and Khyber Pakhtunkhwa, culminating in significant loss of life, the displacement of millions, and harm to agricultural land and infrastructure (The express tribune, 2014). Analogous patterns of destruction were evident during floods in 2014 and 2022, which were fueled by intense monsoon rains and glacial melting. The 2022 floods, characterized as the most catastrophic in Pakistan's history, impacted 33 million people, displacing nearly 8 million, and resulted in over 1,700 deaths, with children constituting one-third of the fatalities (Gishkori, 2022; Ahmed, 2022). These occurrences underscore the nation's susceptibility to climate-induced disasters. Floods not only precipitate immediate fatalities and bodily harm but also engender long-term health complications (Shreshta, 2008). Contaminated floodwaters heighten the risk of infectious diseases, including diarrhea, malaria, leptospirosis, as well as skin and respiratory infections (Baqir et al., 2012). The destruction of healthcare infrastructure, encompassing hospitals and clinics, obstructs the provision of essential medical services and places additional strain on already precarious health systems (Piel et al., 2018). Additionally, Flood causes multiple disorders to vulnerable community's specifically pregnant women and the children in terms of asthma, dermatological cancers, vomiting and worsening the health conditions presenting diverse health disorders affecting life at greater extent. According to UNFPA (2022), approximately 650,000 pregnant women were impacted by the floods of 2022, with over 73,000 anticipated to give birth within a month, many lacking access to sufficient healthcare services.

However, the healthcare system in Pakistan are well noted by insufficient infrastructure regarding disaster management and poor government frameworks. Political inadequacies and inadequate allocation of resources have impeded effective interventions during health emergencies triggered by natural calamities (Rehman, 2022). For example, the devastation of more than 2,000 healthcare facilities during the floods of 2022 interrupted immunization initiatives and heightened the susceptibility to disease outbreaks, particularly within displaced communities (Shafi et al., 2022).

The economic ramifications of climate-induced disasters in Pakistan are profound, with estimated losses reaching $80 billion from 1996 to 2016 (Ilyas, 2022). Inefficient land management, absence of strategic urban planning, and substandard flood management protocols further intensify the nation's susceptibility. Scholarly research underscores the pressing necessity for comprehensive reforms in developmental strategies and resource allocation to enhance resilience against natural disasters. This entails addressing disparities in health access, augmenting reproductive healthcare services, and guaranteeing sufficient housing and sanitation for populations affected by flooding (Lockie, 2017).

Confronting these issues necessitates collaborative efforts to embed health considerations within disaster management frameworks. Enhancing healthcare infrastructure, bolstering governance, and ensuring equitable access to crucial services can mitigate the enduring consequences of floods on public health and overall welfare.

Methods

In order to collect data for the present investigation, we curated a selection of 40 esteemed scholarly articles from diverse online repositories and platforms, including Google Scholar, Science Direct, Websites, and Scopus as highlighted in Fig-2. The selected documents were published within the timeframe of 2003 to 2022. Particular emphasis was placed on contemporary literature that has garnered significant citations. The criteria for the selection of

pertinent literature were fundamentally anchored on the following considerations: Research articles disseminated in peer-reviewed journals possessing an established impact factor. Peer-reviewed scientific reports concerning floods published by globally acknowledged publishers. News articles. Literature that integrated keywords such as flood, climate, health, social impacts, developing nations, and floods in Pakistan.

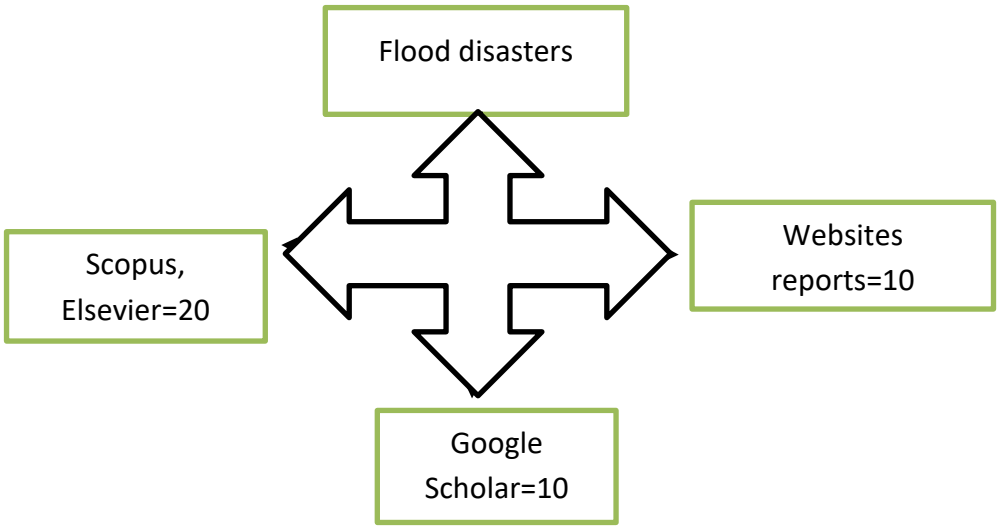


Fig-2: Literature Search Sources

Results and Discussion

With regards to the flood destruction and its impacts on health, table-1 shows the health impacts of flood focusing different research. Where the data was conducted from the various sources of Search engines and the websites. Major health impacts due to flood shown as the, Mortality, Injuries and Health Issues, Mental Health, Infectious Diseases, Waterborne Diseases, Maternal Health, Children's Health, Damage to Healthcare Systems, Malnutrition, Vector-borne Diseases, and Respiratory Illnesses. The results have highlighted that, the floods in Pakistan have caused severe health-related consequences in various aspects. Death tolls have been significant, with more than 1,700 fatalities in the 2022 floods, of which 33% were children, alongside major losses in previous disasters, including 2,000 deaths in 2010 and 815 in 2003. Numerous households reported injuries and health problems, with 77% being affected during the 2010 floods. Widespread cases of diseases such as malaria, diarrhea, leptospirosis, and respiratory infections were observed throughout these events. Mental health issues, such as psychological distress, became increasingly common. Infectious diseases like malaria, dengue, and hepatitis E, as well as waterborne diseases such as cholera and typhoid, surged due to contaminated water supplies. Maternal health was significantly affected, with over 73,000 pregnant women in 2022 unable to access adequate care due to damaged infrastructure and sanitation issues. Millions of children were at risk of malnutrition and diseases, with the 2022 floods impacting 16 million. Healthcare systems were overwhelmed, with over 2,000 facilities damaged in 2022, disrupting vaccination and essential medical services. Food shortages and is Placement exacerbated malnutrition, while stagnant floodwaters increased mosquito-borne illnesses such as dengue and malaria. Overcrowding in shelters further led to rising respiratory infections, reflecting the extensive health crisis caused by these disasters.

Table 1: Health Impacts of Flood on Local Life

Health Impact Area	**Details**	**Flood Event/Year**	**Source/Reference**
Mortality	Over 1,700 deaths, with	2022 Floods	Pakistan Floods (2022),

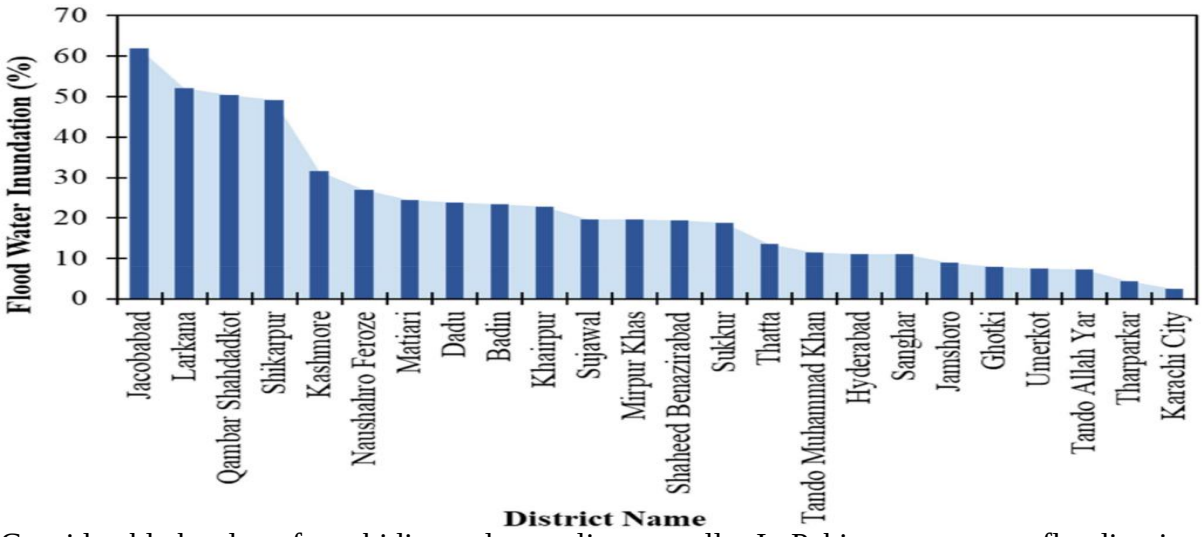
	33% being children.		Giskori (2022)
	At least 2,000 fatalities.	2010 Floods	Pakistan Floods (2010), Zaidi (2010)
	Over 815 deaths due to flash floods.	2003 Floods (Sindh & Balochistan)	Islamic Relief Worldwide (2009), Monson (2011)
Injuries and Health Issues	77% of households reported injuries or health conditions.	2010 Floods	Kirsch et al. (2012)
	Increased cases of leptospirosis, malaria, diarrhea, and respiratory diseases.	Multiple Floods (2003-2022)	Baqir et al. (2012), Bandino et al. (2015)
Mental Health	Increased psychological stress and mental health disorders.	Recurrent Flood Events	Paavola (2017)
Infectious Diseases	Outbreaks of malaria, dengue, hepatitis E, and gastrointestinal diseases.	2022 Floods and Earlier Events	Khan (2022), Salek et al. (2020)
Waterborne Diseases	Widespread cholera and diarrhea due to contamination of drinking water supplies.	2022 Floods	UNFPA (2022), Shah et al. (2020)
	Increase in typhoid and dysentery cases.	2010-2022 Floods	Winter et al. (2022)
Maternal Health	73,000 pregnant women expected to deliver without adequate medical facilities.	2022 Floods	UNFPA (2022), Salek et al. (2020)
	Severe challenges due to lack of sanitation, hygiene products, and health services.	Multiple Flood Events	UNFPA (2022)
Children's Health	Approximately 16 million children were affected, with many at risk of malnutrition and disease outbreaks.	2022 Floods	Giskori (2022)
Damage to Healthcare Systems	Over 2,000 healthcare facilities damaged or destroyed, impacting vaccination campaigns and treatment services.	2022 Floods	Geddes (2022), Rehman (2022)
	Disruption to critical healthcare services and lack of medical resources.	Multiple Floods (2003-2022)	Piel et al. (2018), Bandino et al. (2015)
Malnutrition	Significant rise in malnutrition due to food shortages and displacement.	2010 and 2022 Floods	Pakistan Floods (2010, 2022)

Vector-borne Diseases	Increase in mosquito-borne diseases like malaria and dengue due to stagnant water.	Multiple Flood Events	Baqir et al. (2012), Daniel et al. (2021)
Respiratory Illnesses	Rising respiratory infections due to overcrowding in shelters and poor air quality.	2022 Floods and Earlier Events	Baqir et al. (2012)

Floods destruction in Sindh Province

Fig-3 shows the flood destructions in different areas of Sindh province of Pakistan. Where High rate of flood destruction presented in picture is in Jacobabad with almost 60%. Besides that, Larkana and Qambar Shahdadkot has considered to be the second highest affected areas in Sindh with almost 50%. Following that, the other areas were also presented with different percentage. Results show that, northern areas were affected by flood at greater extent.

Climate change has precipitated substantial ecological disturbances, which have subsequently resulted in significant health repercussions (Khoso et al., 2024). Global phenomena such as flooding and extreme meteorological events impose a



Considerable burden of morbidity and mortality annually. In Pakistan, recurrent flooding is a direct consequence of the nation's pronounced monsoon precipitation. Any nation would encounter formidable challenges in managing floods of the severity and scale witnessed in recent years in Pakistan (BBC, 2014). These inundations have underscored critical deficiencies in the country's existing capabilities, including insufficient warning systems, limited readiness, ineffective disaster response, and the absence of comprehensive flood management strategies (Rehman, 2022).

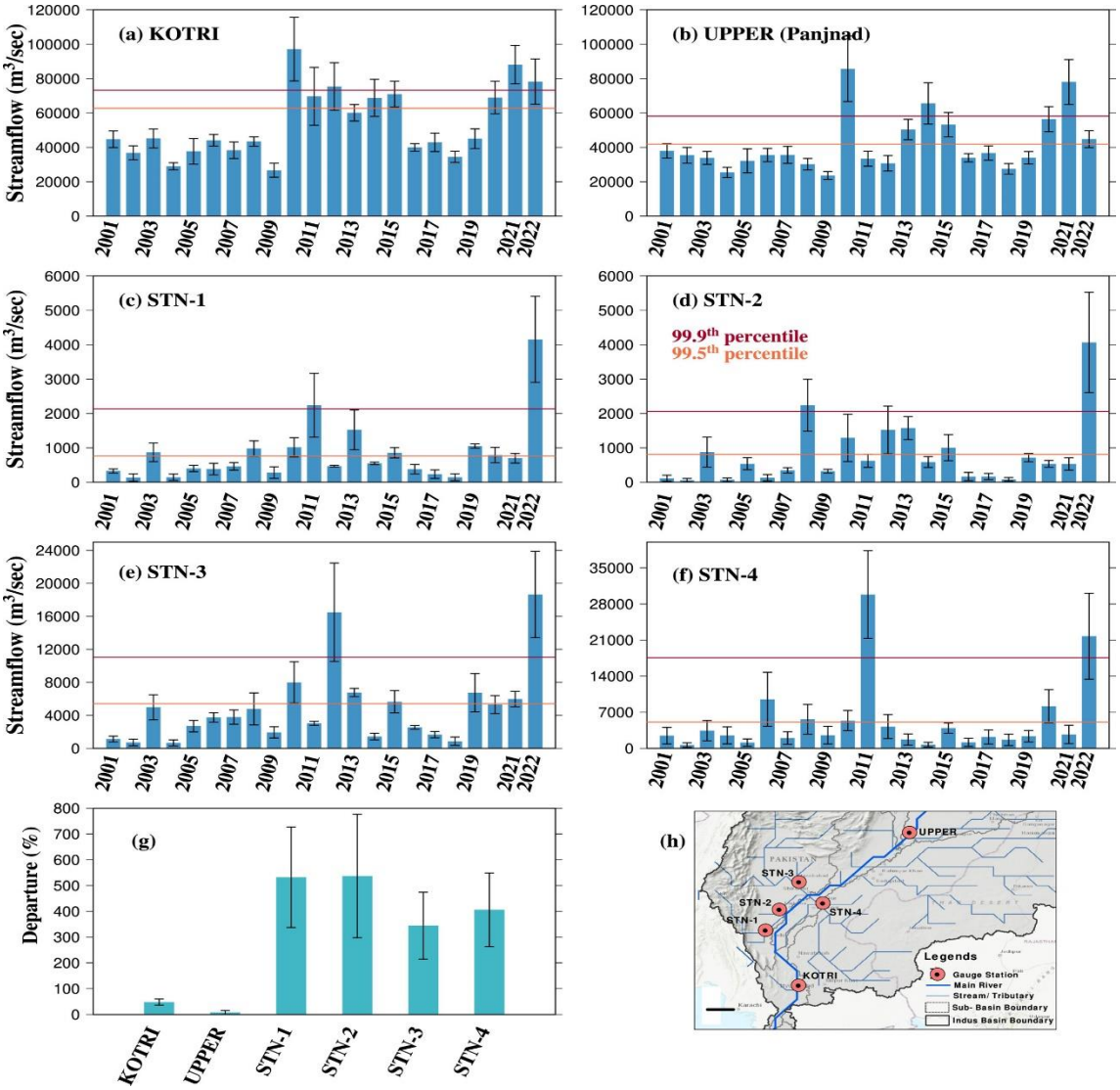


Fig-4: Streamflow simulation of along Indus basin (Source: (Nanditha et al 2023)

The figure-4 illustrates annual stream flow data from 2001 to 2022 for several gauging stations along the Indus River and its tributaries, highlighting notable spatial and temporal variations. Sub-figures (a) and (b) depict stream flow trends at the Kotri Barrage and Upper Panjab stations, showing significant increases during high-monsoon years such as 2010 and 2022, with flows exceeding historical thresholds. Sub-figures (c) to (f) provide data from four sub-stations (STN-1 to STN-4), where sharp spikes are evident during extreme flood years, particularly 2010, 2013, and 2022, when stream flow's surpassed the 99.9th and 99.5th percentile thresholds (red lines). Sub-figure (g) illustrates the percentage departure of stream flow from average levels across all stations, with STN-1, STN-2, STN-3, and STN-4 showing larger deviations compared to Kotri and Upper Panjab. The accompanying map (h) identifies the locations of these gauging stations within the Indus River Basin. Overall, the figure highlights the increasing intensity of extreme hydrological events in the region, likely influenced by climatic and monsoonal variability.

Consequently, the nation confronts considerable health threats, with elevated mortality rates following substantial flooding incidents (Bell, 2011). This research analyzed patterns of

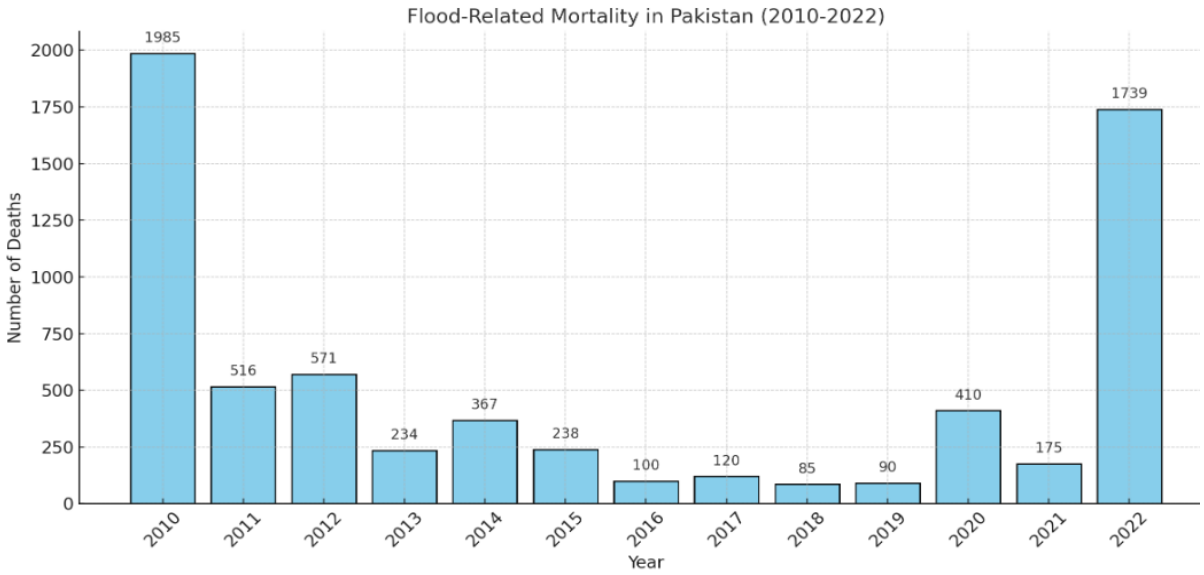


Fig-5: Flood related mortality in Pakistan (2010-2022) (WHO-2023)

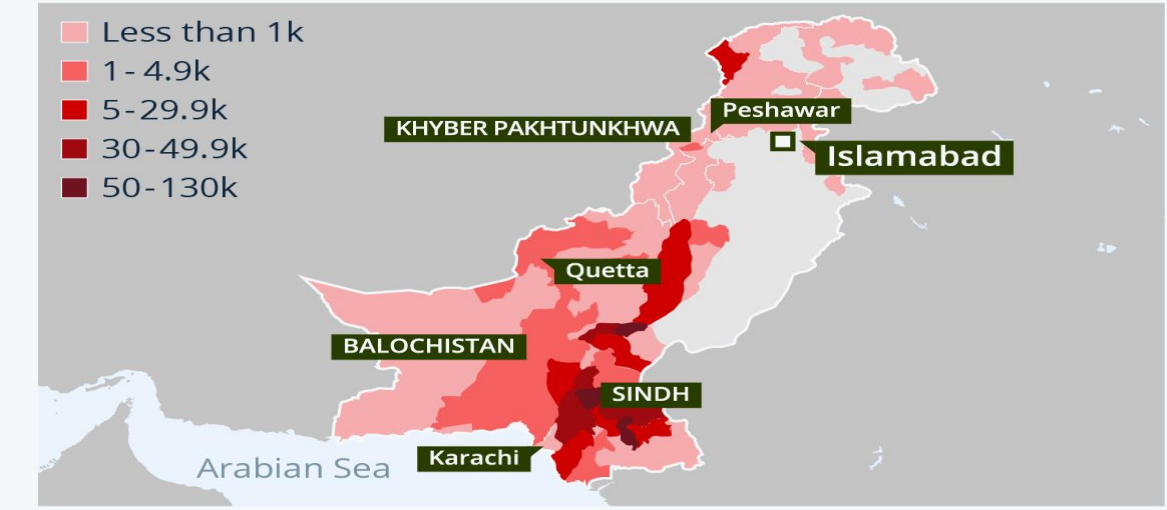
Illness to evaluate the susceptibility and health ramifications of flooding. A systematic review of various reports and studies disclosed that extreme weather events intensify health issues, particularly within displaced and unsanitary populations, where outbreaks of diseases such as fever, dengue, and gastrointestinal disorders are prevalent (Fox, 2019).

Flood related mortality rates have been extended at greater extent in 2010. As predicted in fig-5, that mortality rate in 2010 was almost 1985 and many of the households have been displaced that not only affected the lives but also the source of income, houses, and caused displacement at greater extent. While, the figure has some further fluctuations in different years. So far, death rates in 20222 were further considered to be the second high with 1739. The literature above highlighted that the death rates in northern areas of Sindh were consequently noted with displacement as well as health concerns.

Furthermore, flood-affected individuals frequently endure psychological distress and mental health complications. Our extensive literature review indicates that efficacious policies are imperative to diminish flood-related morbidity and mortality. Catastrophic flooding has profound effects on both physical and mental health, often through the proliferation of bacteria, viruses, and other pathogens. Such diseases can encompass diarrhea, cholera, dengue fever, and hepatitis E. Stagnant floodwaters create optimal environments for mosquitoes and other disease vectors. Beyond infectious ailments, the ramifications of flooding also encompass long-term health issues, including chronic respiratory conditions, anxiety, and depression. Displaced populations are especially vulnerable, as they often lack access to clean water, sanitation, and healthcare services. Specific demographics, including the elderly, pregnant women, children, and those with pre-existing health concerns, exhibit heightened susceptibility.

Low-income communities residing in informal settlements are particularly at risk, as they frequently inhabit flood-prone regions and lack essential infrastructure and services (Dawn, 2012). Indigenous populations, migrant laborers, and refugees are also more exposed due to restricted access to healthcare and legal safeguards (Chaudhry, 2017). The research findings underscore the necessity for extensive recovery initiatives to alleviate the health and economic consequences of flooding in Pakistan. Floods inflict severe damage on infrastructure, diminish productivity, and escalate healthcare expenditures. This situation necessitates a concentrated effort to restore employment, agricultural systems, and private households (BBC, 2014). The revival of public health facilities and the reconstruction of vital infrastructure, such as roads, bridges, and educational institutions, are also crucial. To attain these objectives, a comprehensive framework for resilient recovery, rehabilitation, and reconstruction is indispensable. Pakistan requires a transparent and inclusive strategy, grounded in collaboration among the public and private sectors, academic institutions, think tanks, and the international community, wherein all stakeholders work towards a unified

Fig-6: Flood affects in Pakistan, 2022.



Source: UN Office for the Coordination of Humanitarian Affairs Pakistan

Objective. Concurrently, disaster preparedness and response initiatives should prioritize the protection of the most vulnerable populations. The implementation of effective policies and interventions can mitigate the health impacts associated with floods and extreme climatic events.

According to UN, in 2022, more than 30 million people were affected due to the monsoon floods, where the Sindh province was affected at large as shown in the fig-6. This investigation does not concentrate on specific interventions, indicating that further research is essential to address this deficiency. Future research endeavors ought to investigate various vulnerability determinants, encompassing social, economic, and political dimensions. Furthermore, there is a necessity for investigations into community-centered interventions that can enhance resilience and mitigate flooding impacts. The formulation of effective policies and strategies is imperative to curtail the economic repercussions instigated by floods and to foster sustainable development (Global Register of Major Flood Events, 2007). This extensive review underscores the critical necessity for interventions aimed at diminishing flood-associated morbidity and mortality. Catastrophic floods can yield significant health repercussions, particularly for at-risk populations. The deployment of efficacious policies and

interventions can bolster resilience against prospective extreme weather phenomena. Additional research is warranted to evaluate the efficacy of such interventions and to comprehend the elements that heighten vulnerability to flooding events. A synergistic, multi-sectoral strategy is essential to tackle the health ramifications of floods, necessitating collaboration among governmental entities, civil society, and the private sector.

Conclusions and Strategies

The focus of this research mainly relied over the health impacts on livelihood regarding the flood. The literature based research provided a sight full consequences regarding the flood and its impacts on health. On behalf of the results, the study concludes that that climate change has been the major factor of flood including heavy rainfall as predicted in the literature. It is also concluded that the flood affected health concerns noted in the literature was asthma, respiratory issues, skin irritations, malaria and other were well observed specifically in children, pregnant women, elder and the old age. Where, there is a need of health interventions in the study area to fulfil the gap and provide a better environment and sustainability. Government policies have a key role to play in increasing health access and managing disaster risks during floods. This includes ensuring access to podiatry and mental health services. A proactive and coordinated humanitarian response is essential to reduce health disparities and support the well-being of displaced populations. Governments can implement strategies to mitigate the health impacts of floods, such as subsidies, tax exemptions, and other financial measures. This approach requires addressing the political and social factors that influence flood management decisions. Ecosystems play a key role in shaping climate change and can be key factors in building social resilience. Managing ecosystems based on principles of biodiversity science can help communities adapt to climate change. Flood risk management strategies can help address gaps in disaster preparedness and response. Effective flood management depends on active participation, coordination, and engagement of the public and private sectors, with clear and enforceable regulations. It is important to create a balance of certainty and flexibility in regulations to respond to changing circumstances.

Limitations of the study

The study is in line with literature based research which has some certain limitations, firstly, the research should be carried out to conduct primary data on mixed method approaches to gain more justifiable results. Secondly, the research is only a literature, conducting systematic analysis or secondary analysis could provide more benefits in research outcomes. Thirdly, the research should be carried out on comparative parameters to be adjusted for policy measures to be taken for better health conditions.

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