

# Contextualizing linkages between water security and global health in Africa, Asia and Europe. Geography matters in research, policy and practice

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## ABSTRACT

The linkages between water security and global health vary in space and time. Just like water connects every aspect of life, geography relates everything to everything else. Therefore, in order to address challenges at the interface of water security and global health, the use and application of medical geography, a sub-discipline of geography, is helpful in research, policy and practice.

Using different water security pathway classifications (diminished water supply or quality, increased water demand, and extreme flood events) and the United Nations Sustainable Development Goals and targets as a frame, this paper looks at water and health challenges from different angles and from a holistic perspective, while contextualizing them. Drawing on five practical examples, including water-related infectious disease exposure in watersheds in semi-arid Kenya, health system response in floodplains in Namibia, public health implications in a protracted emergency setting in arid Northeast Nigeria, water, sanitation and hygiene (WASH) monitoring in households, schools and healthcare facilities in Small Island Developing States in the South Pacific, and WASH-related challenges and disease exposures among marginalized ethnic minority populations in Europe, the applicability and usefulness of geography contextualizations in research, policy-makers and practitioners is presented. Moreover, cross-cutting topics and contextualizations, beyond water security and global health, including climate- and weather-related extreme events, inequality, health- and water-related education, risk perceptions and behaviour, and the cultural context, are highlighted to showcase the value of applying medical geography in *understanding* the key drivers, barriers and bottlenecks in complex situations; *recommending* actionable and contextualized measures to address these challenges; *directing* programming and interventions; and *informing* policy-making to tackle and solve these challenges.

## 1. Setting the Scene: Water matters and the use of geography

Geographers are trained to see and understand the world and all physical and human geographical processes in their complexity, multi-dimensionality, and cause-and-effect relationships. Geographers adopt different approaches, perspectives, quantitative, qualitative and geo-spatial methods, and most importantly, contextualize the topic under investigation in space and time [1–4]. Whether and how such contextualizations add value to address the interface of water security and global health in research, policy and practice has not yet been comprehensively framed.

### 1.1. Conceptualizing water security

Water connects not only rivers and tributaries, springs and estuaries, coastlines and oceans, ports and places, but every aspect of life. Water, the lifeline that covers 71 % of our planet, is at the core of sustainable development, critical for socio-economic development, energy and food production, healthy ecosystems and human health and well-being, serving as the crucial link between society and the environment [5].

Water security is a broad concept that is being used across disciplines, emphasizing sustainability, infrastructure, human capabilities, ecosystem health, governance, production and agricultural needs, and societal relations with water [6–9].

The Ministerial Declaration of The Hague on Water Security in the 21st Century, issued at the World Water Forum in 2000 [10], expanded

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global interest in and uptake of water security in global policy, development, and science agendas. It describes the water security challenge as “ensuring that... ecosystems are protected and improved; that sustainable development and political stability are promoted, that every person has access to enough safe water at an affordable cost to lead a healthy and productive life and that the vulnerable are protected from the risks of water-related hazards” [11].

Water security definitions differ in their level of analysis, with emphasis ranging from the national to individual and water-source level [12]. Gleick and Iceland [13] classify water and security pathways under three broad categories: diminished water supply or quality, increased water demand, and extreme flood events. According to the authors, no single strategy is sufficient to reduce water risk, but instead, multifaceted approaches are needed. In this paper, Gleick and Iceland’s categories are adopted to frame water security matters in the context of human health, including both household and non-household levels.

### 1.2. Linking water security with global health and exposure to water-related diseases

The United Nations call for looking at water and the water cycle in its entirety, including all uses and users, and at the water-related Sustainable Development Goals (SDG) from a holistic perspective [8]. SDG 6 aims to ensure availability and sustainable management of water and sanitation for all, thereby connecting the main aspects related to freshwater. UN-Water’s illustration shows how the targets within SDG 6 cover the water cycle in an integrated manner [8], Fig. 1), contextualizing targets 6.1) safe drinking water, 6.2) adequate sanitation and hygiene, 6.3) water quality and wastewater, 6.4) water use and scarcity, 6.5) water resources management and 6.6) ecosystems, 6a) international cooperation and 6b) stakeholder participation.

Providing water security and guaranteeing access to sufficient water supply of good quality (security through water) while also protecting communities from water-related threats such as flooding and other extreme weather events (security from water) are crucial to promote human health Bündnis Entwicklung Hilft and Ruhr University Bochum – Institute for International Law of Peace and Armed Conflict [14]. Interactions between water security and human health are subject to spatiotemporal dynamics and differ between different locations– between neighbourhoods; urban, peri-urban, and rural areas and informal settlements; with socio-economic disparities; between low-, middle- and high-income countries; in different cultural contexts; at different scales, ranging from local to national to regional to continental; they are strongly determined by geography, with place and environmental, climatic and hydrological factors, exposures to natural (and water-related) disasters, available health systems and services in terms of prevention, treatment and care; and access to education and different levels of health-related knowledge, risk perceptions and behaviours [4], determining communities’ and individuals’ water-related health risks and exposure to diseases.

The so-called ‘Bradley Classification’ [15] classifies water-related

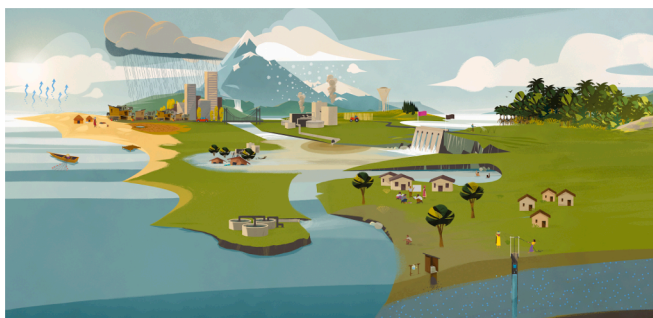


Fig. 1. The Water Cycle in the Sustainable Development Goals [8].

infectious diseases, showing entry points towards disease prevention related to the provision of safe water, sanitation and hygiene (WASH) [16]. Accordingly, waterborne diseases are caused by the ingestion of diverse viral, bacterial, protozoal and helminthic pathogens in drinking water and are thus determined by the water quality at the point of use [17,18]. Water-washed disease transmission is driven by the availability, access and use of water for hygiene, referring to water as a preventative factor of person-to-person transmission when sufficient water quantities are available. Water-based diseases cover those pathogens that spend a necessary part of their life cycle in water. Water-related insect vector transmission involves insects that breed in or bite near water acting as transmission vector [16].

Diseases entirely or partially attributable to or linked with inadequate WASH infrastructure and behaviours [19,20], mainly affect rural, informal and indigenous communities in low- and middle income countries, as well as minority populations and low socio-economic and other groups in high-income countries [21] who carry the greatest disease burden [22].

### 1.3. Contextualizing links between water security and global health with medical geography considerations

The linkages between water security and global health underly spatiotemporal dynamics, and vary in space and time. Just like water connects every aspect of life, geography, according to Waldo Tobler, relates everything to everything else [23]. Therefore, in order to address challenges at the interface of water security and global health, the use and application of medical geography, a sub-discipline of geography, is helpful in research, policy and practice.

The interconnections of health and geography trace back more than 2000 years, when Hippocrates (460–377 BCE) stated in his work ‘On airs, waters and places’, that whoever wishes to investigate human health properly should not only consider the geographical peculiarities of each locality, seasons of the year, characteristics of water, such as quality and quantity, but also human behaviour, different lifestyles and habits [24,25]. The classic “modern” example of linking water security, human health (or disease) and geography was John Snow identifying the London Broad Street pump as the source of a major cholera outbreak in 1854, with individuals using the pump as main water sources exposing themselves to cholera [26,27].

The investigation of relationships between health and diseases in space and time, the application of geographical concepts and methods to water-related health problems and diseases [28], links between environmental factors (e.g. the impact of extreme weather events), water security parameters (e.g. drinking quality and quantity) and health indicators or factors exposing to disease, their visualization on maps, associating the health challenges of interest with topographical, hydrological, climatological, population, infrastructure, cultural context, policy and economy involves disease ecology or geographic epidemiology, health system and services research [28–30]. The focus of medical geography on spatio-temporal disease patterns and disease mapping was thematically and methodologically developed further to a geography of health [2,31–34].

Multi-, interdisciplinary and holistic approaches through adaptation of public health, epidemiological and sociological methodologies are gaining increasing attention [29,35], corresponding to the call for multifaceted approaches to address water security issues by Gleick and Iceland [13]. Traditional mapping and quantitative approaches are complemented by additional research methods, including mixed methods, more qualitative and participatory research [36], subjective feelings towards places, health beliefs and health-related behaviour [37,38].

In the context of low- and middle-income countries, aspects related to geography and health mainly address infectious diseases and environmental (change-related) health risks Haggett [39], the epidemiological transition and inadequate health systems, inadequate WASH

[40,41] and waste management, as well as limited preventative health measures.

## 2. Holistic, interdisciplinary, mixed methods approaches to contextualize water security and human health research

This article showcases the applicability and value of geography as one of the most suitable disciplines to address and contextualize complex challenges of water security and global health. Drawing on other holistic and interdisciplinary approaches such as One Health, EcoHealth and Planetary Health [42,43], critical physical geography [44,45] and boundary-spanning [46,47] (Table 1), medical geography approaches in particular can bridge different health- and health system-related contexts; local, regional, national and global perspectives and priorities; and research, policy and field practice.

Ultimately, related research, involving the target population(s) as key informants, can assist policy-makers and practitioners *understand* the key drivers, barriers and bottlenecks in complex situations; *recommend* actionable and contextualized measures to address these challenges; *direct* programming and interventions; and *inform* policy-making to tackle and solve these challenges.

In the following, five practical examples of medical geography research are summarized to showcase its value for policy and practice. These include water-related infectious disease exposure in watersheds in semi-arid Kenya, health system response in floodplains in Namibia, public health implications in a protracted emergency setting in arid Northeast Nigeria, WASH monitoring in households, schools and healthcare facilities in Small Island Developing States in the South Pacific, and WASH-related challenges and disease exposures among marginalized ethnic minority populations in Europe (Fig. 2; Table 2).

Using Gleick and Iceland's [13] classification of water security pathways (diminished water supply or quality; increased water demand; extreme weather events), and the 2030 Agenda for Sustainable Development, its sustainable development goals and targets [48] as a frame, this paper shows the contribution of the individual case studies to

**Table 1**

Holistic and interdisciplinary approaches not to be confused with medical geography.

Approaches	Definition or framing	Reference
Boundary-spanning	"the practices of 'reaching across borders, margins, or sections to build relationships, interconnections and interdependencies in order to manage complex problems', of relevance to the development of global health thinking. Requires a mindset for learning—that goes upstream: to draw out general or global lessons from the particulars of the local; downstream: for effectively applying global guidance for local practice and evaluating its relevance; and also laterally: for learning from different and comparable contexts.	[46,47]
Critical physical geography	"attention to biophysical landscapes and the power relations that have increasingly come to shape them, and the politics of environmental science and the role of biophysical inquiry in promoting social and environmental justice.	[44,45]
EcoHealth	"more of a biodiversity focus, with an emphasis on all living creatures, implying that parasites, unicellular organisms, and possibly also viruses have a value and should be protected."	[42,43]
One Health	"a narrow approach combining public health and veterinary medicine" or "a wide approach including both scientific fields, core concepts, and interdisciplinary research areas." In both cases, the focus is usually on safeguarding the health of vertebrates, while ecosystems are also included in the model.	[43]
Planetary Health	"fruitful approach to deal with growing threats in the health area, not least globally."	[43]

addressing and helping to achieve some of these goals related to water security and global health.

Building on the consideration that no single strategy is sufficient to reduce water risk, but instead, multifaceted approaches are needed [13], all included studies follow the concept of triangulation; a method which serves to analyze a phenomenon by combining data from different sources and levels on the same research topic (data triangulation); applying different methods (methodological triangulation); applying different theories or hypotheses (theory triangulation); and employing different people for the collection and analysis of the data (investigator triangulation) [49–51].

Building on the consideration that geography relates everything to everything else [23], cross-cutting topics and contextualizations, beyond water security and global health are highlighted, including climate- and weather-related extreme events, inequality, health- and water-related education, risk perceptions and behaviour, and the cultural context of water and health implications.

### 2.1. Assessing health risks and recommending health-promoting wetland management

Across Sub-Saharan Africa, wetlands often constitute the only accessible water resources in otherwise uninhabitable landscapes, which is why they are being used extensively for domestic and agricultural purposes [52]. The resulting degradation and contamination of water has the potential to spread disease-causing microorganisms and provide increased breeding habitats for disease vectors [53]. Knowledge gaps remained about whether and how different kinds of wetland use influence the exposure to health risks and transmission of infectious diseases.

#### 2.1.1. Research approach and methodology

A study on water-related infectious disease exposure in a wetland in semi-arid Kenya (2013–2017), funded by the German Federal Ministry of Education as part of the project *GlobE Wetlands in East Africa – Reconciling future food production with environmental protection*, aimed at

- Identifying health risks and water-related infectious diseases that can be present in wetlands and associating them with wetland uses.
- Assessing health risks arising from wetland use and linking them to the wetland users' health-related behaviour.
- Estimating health risk perceptions of the wetland users towards these identified and assessed health risks and diseases.

This study involved different disciplines, such as medical geography, epidemiology, public health, social science, water resources management, WASH, agriculture, environmental sciences and others. A mix of quantitative and qualitative empirical research was conducted with different respondent groups (commercial farmers, smallholder farmers, pastoralists, service sector workers) that represented differing cultural contexts and community versus service provider perspectives.

Information on water-related diseases previously associated with wetland use was retrieved through an extensive narrative review of peer-reviewed academic literature [54]. The information was used to develop the data collection tools, both quantitative and qualitative, for the empirical part of this study which involved different wetland user groups: farmers, nomadic pastoralists, and service sector workers. A syndromic surveillance or self-reporting of disease approach [55] and an observational spot check [56] were used for the quantitative assessment of health risks [55] arising from wetland use in the surveyed population. Health risk perceptions were captured through in-depth interviews [57], and health seeking-behaviour was analyzed based on mixed quantitative and qualitative methods [58]. What was taught on WASH and related health risks in schools was analyzed as well [59]. Moreover, expert interviews with representatives from the health, water, education sectors and others were included to capture a service provider perspective besides the community perspective [58] (Table 2).

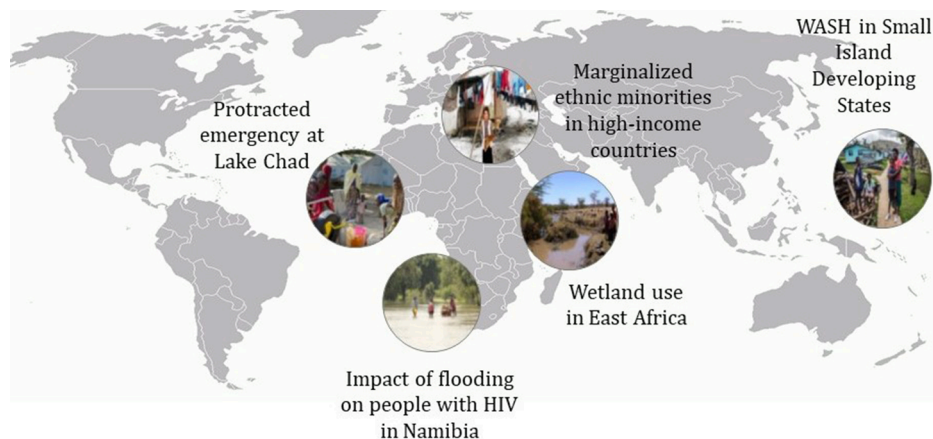


Fig. 2. Contextualizing linkages between water security and global health.

### 2.1.2. Main findings and contextualization with geography

The study revealed that the literature base available on use-related disease exposure does not reflect real risks the community is facing. These real risks differ between different occupational groups, and are perceived differently in different cultural contexts and with varying prevailing health beliefs.

While the farmers live in close proximity to the swamp and interact closely with the water it provides, pastoralists live in the drier, more remote and distant surroundings of the swamp. Pastoralists face and perceive greater challenges related to water scarcity, and the use of predominately unimproved and unsafely stored water sources, lack of (environmental) hygiene, lack of sanitation facilities, open defecation [56] and related diseases as compared to the majority population [55]. Social and cultural factors, as well as traditional semi-nomadic lifestyle in close proximity to their livestock, mattered in terms of awareness and understanding of the ‘meaning’ of health and ill-health, their risk perception and related uptake of health-related protective measures, interactions with water and the wetland, exposure, transmission, prevention and treatment [57]. Compared to the other groups, the pastoralists were also less likely to consult a healthcare provider for cure from disease. Major determinants included distance and access to healthcare facilities, cost, educational background and health beliefs that drive health choices among pastoralists [58].

Disease exposure, health-related perceptions and behaviours varied in the proximity to the water body: In the wetter areas, breeding sites are vastly available, favouring the reproduction of mosquito vectors, and thus potentially increasing vector-related diseases such as malaria. The accumulation of wastewater, sewage, faecal matter and other disease-causing agents in the swamp contaminates the wetlands’ water. A decrease of water quality is accelerated by poor sanitation and sewage infrastructure and leads to the spread of waterborne diseases like diarrhoea, cholera and typhoid fever. All of these adverse health effects are significantly accelerated during heavy rains and flooding, as not only contaminants from the surrounding areas, but also from higher grounds accumulate in the low lying swamp. In the drier areas, the most pressing health challenge that the people are facing is the shortage of water. The resulting lack of hygiene, along with a lack of sanitation facilities and limited water supply makes such arid areas conducive environments for the spread of water-washed diseases such as trachoma, and for waterborne diarrhoeal diseases, while also malnutrition and food insecurity are more widespread too [55,57].

### 2.1.3. Implications for policy and practice

This study underpinned the vital role of wetland users as key informants and demonstrated that risk perception studies and resulting recommendations from the grassroots level serve as helpful supportive tools for health-promoting wetland management which requires a

sensitive, integrative approach that takes into consideration any and all of the humans, ecology, and animals affected [57].

The resulting recommendations for wetland and health managers entail a list of detailed practical measures at the policy and implementation level to adopt for an improved locally-informed health-promoting wetland management. They are relevant on the national and international level, for global policy-making and for achieving progress towards the SDG, including targets 3.3) on malaria, neglected tropical diseases, water-borne diseases and other communicable diseases; 6.1) safe drinking water; 6.2) adequate sanitation and hygiene; 6.4) water use and scarcity; 6.5) water resources management; and 6.6) ecosystems.

## 2.2. Directing health interventions in a protracted emergency

Globally, a large number of protracted and complex humanitarian crisis combined with acute public health emergencies have evolved over the last years, forcibly displacing millions of people, and stretching the humanitarian system at its edge [60]. Where health and political systems collapse, the humanitarian system has taken over the role of providing life-saving and life improvement measures. The Lake Chad region, for example, has become the location of one of the world’s most complex humanitarian protracted crisis, exacerbated by violent extremism, a weak health care system with regular multiple disease outbreaks, as well as social and environmental challenges – including food insecurity, water scarcity, demographic challenges, and widespread poverty, affecting about 17 million people in the region [61].

### 2.2.1. Research approach and methodology




In order to study public health matters in a protracted emergency in an arid area, this study was conducted in North East Nigeria in collaboration with the Emergency Management Unit of the World Health Organization Nigeria (2018), funded by the World Health Organization. It aimed at

- Understanding health-related determinants in a protracted crisis in North East Nigeria.
- Harmonizing and directing future humanitarian and health interventions in the conflict area.

This study involved different disciplines cross-cutting with water scarcity and public health in the context of a humanitarian crisis, such as epidemiology, nutrition, food security, gender, climate change, hydrology, conflict management and peacekeeping.

Information was collected through a comprehensive review of peer-reviewed academic literature and grey literature - including reports, briefs, and secondary data from humanitarian databases (Fewsnets,

**Table 2**  
Holistic, interdisciplinary, mixed methods approaches to contextualize water security and human health research.

	Wetland in Kenya	Protracted emergency in Nigeria	Floodplain in Namibia	Small Island Developing States in Pacific	Underserved minority in Europe
Case study					
Context	Assessing health risks	Directing health interventions	Understanding health sector response	Strengthening WASH and health systems	Obstacles to improvement of WASH
Diminished water supply or quality	x	x		x	x
Increased water demand	x	x			x
Extreme weather events	x	x	x	x	
disease exposure	x	x	x		x
health systems	x	x	x	x	x
WASH	x	x		x	x
infrastructure			x	x	x
risk perception & behaviour	x	x	x		x
cultural context	x				x
WRM	x				
weather / climate	x			x	
flooding	x		x	x	
drought	x	x	x		
food security	x	x	x		
emergency	x	x	x		
gender	x	x	x	x	
education				x	x
inequality				x	x
literature review	x		x		x
document review		x			
secondary data analysis	x	x			
grounded theory	x		x		x
household survey	x			x	
syndromic surveillance	x				
observational spot check	x				
key informant interview	x	x	x		
focus group discussion	x		x		
feedback meeting	x		x	x	
geospatial analysis	x		x	x	
farmers	x				
nomadic pastoralists	x				
service sector workers	x				
community members	x	x	x	x	x
patients			x		x
health	x	x	x	x	
water	x	x		x	
education	x		x	x	
environment		x		x	
agriculture		x			
climate		x			
emergency		x	x		
urban planning				x	

This table is based on case studies from Kenya [54–59], Nigeria [61]; Namibia [64]; Fiji, Kiribati and the Solomon Islands [67–71] and Europe [21].

Reliefweb, UNOCHA, WHO etc.). Based on the review results, in-depth key informant interviews were carried out with strategic stakeholders operating in the area. These included (i) representatives of the regional government of Borno State from different sectors - including health, water, WASH, environmental and agricultural sector - and (ii) representatives of humanitarian and United Nations organizations active in the area - including Médecins Sans Frontières (MSF), World Health Organization (WHO), United Nations Children's Emergency Fund (UNICEF), International Federation of Red Cross and Red Crescent Societies (IFRC), World Food Programme (WFP), Food and Agricultural Organization (FAO) and Malteser International (Table 2).

### 2.2.2. Main findings and contextualization with geography

Addressing different health and water-related topics, making use of mixed methods and their triangulation resulted in the identification of risks for the local and internally-displaced population and lead to a robust understanding on the magnitude of the effects of the situation in its complexity, comprehensive of all environmental, political and social aspects. Context-specific feasible measures and recommendations were identified for different actors - policy makers, humanitarian aid and other organizations, and donors - on how they should respond to such crisis and develop interventions that are efficient, effective and sustainable. Such recommendation should guide the work towards mitigating the challenges which lie ahead to keep the region safe from emerging diseases. The resulting roadmap will be used direct future humanitarian practice, health interventions and policies in the protracted emergency area [61].

### 2.2.3. Implications for policy and practice

The recommendations related to the different topics covered in the assessment, and included, among others, integrated risk monitoring and early warning system that integrates data on climate-sensitive environmental risks and epidemiological trends; application of early detection tools (i.e. rapid diagnostics) to identify changing disease incidence, geographic and seasonal risk mapping, and climate-informed early warning systems; establishment of capacity/systems to facilitate monitoring, evaluation and reporting on medium and long-term climate and health co-benefits associated with the climate mitigation measures introduced in the health sector. They inform several SDG targets, such as targets 3.8) universal health coverage; 6.4) water use and scarcity; 6a) international cooperation; 6b) stakeholder participation; 16.1) reduce all forms of violence and related deaths.

## 2.3. Understanding the impact of flooding on health sector response

Floods are a disaster situation for all affected populations and especially for vulnerable groups within communities such as children, orphans, women, and people with chronic diseases such as HIV and AIDS [62,63]. They need functioning health care, sanitation and hygiene, safe water, and healthy food supply, and are critically dependent on their social care and support networks [64].

### 2.3.1. Research approach and methodology

To study the impact of flooding on people living with HIV and AIDS in a floodplain in Northern Namibia (2012), research funded by the German Development Agency (Gesellschaft fuer Internationale Zusammenarbeit) in collaboration with the Ohangwena Ministry of Health and Social Services aimed at

- a. Understanding the impact of flooding on HIV service providers and people living with HIV and AIDS.
- b. Identifying constraints with regard to HIV care provision.
- c. Using the outcome for future management of HIV response in flood-prone regions in order to improve access to services and medication during floods.

A broad review of peer-reviewed academic literature was conducted to approach the implications of flooding on people living with HIV/AIDS (PLWHIV). It covered literature on HIV/AIDS in emergencies; HIV/AIDS and the environment; flooding and human health. The results of the literature reviews were analysed using a grounded theory approach. The outcomes facilitated the development of qualitative data collection tools for the empirical part of this study, including key informant interviews and focus group discussions. The empirical study involved different study populations at different levels: local level (PLWHIV), regional level (service providers, including representatives of governments and civil society organizations), as well as national and international level (government bodies and international and UN organizations working on HIV/AIDS). The empirical results and recommendations were discussed as part of a National Feedback Meeting in the Namibian Ministry of Health, and the resulting changes were included in the study (Table 2). The findings were interpreted using the sustainable livelihoods framework, the natural hazard research approach, and health behaviour theories [64].

### 2.3.2. Main findings and contextualization with geography

Flooding poses major challenges to PLWHIV in terms of their everyday lives, affecting livelihoods, work, income, and living conditions. What is threatening them under normal conditions - poverty, malnutrition, unsafe WASH, limited access to healthcare facilities, a weak health status, and stigma - is intensified by flood-related breakdown of infrastructure, insecurity, malnutrition, and diseases evolving over the course of a flood. A potential dual risk exists for their health: the increased risk both of infection and disease due to the inaccessibility of health services and antiretroviral treatment. Vulnerabilities and health risks of PLWHIV will increase in a disaster situation like flooding if access to HIV prevention, treatment, care and support are not addressed and ensured.

### 2.3.3. Implications for policy and practice

This study brought "all" relevant stakeholders (i.e. emergency and flood management, public health, water, infrastructure, safety and security, gender) together to discuss grassroots challenges of people living with HIV and AIDS in the flood-prone Ohangwena region. The triangulation of results from different levels and perspectives facilitated a detailed understanding of the situation and of the challenges that the population is facing. Measures and recommendations to reduce the negative impact that floods cause on HIV and AIDS care and to facilitate the future continuation of care during flooding as well as improved disaster response were identified: pre-active clarification of responsibilities, improved communication, and coordination of all sectors involved; inclusion of detailed capacity and vulnerability assessment of flood-affected populations in disaster response plans; application of lessons learned from previous floods to strengthen capacity and identify potential gaps; reduction of flood-related risks for PLWHIV and other chronically ill and vulnerable groups through integrated disaster preparedness measures for future floods; and improvement of disaster preparedness by applying the resulting *HIV and Flooding Framework* [64]. Considerations and recommendations from this research inform several SDG targets, such as targets 3.3) related to AIDS; 3.8) universal health coverage; 11.5) water-related disasters.

## 2.4. Using data to strengthen national water, sanitation, hygiene and health systems

The ability of Small Island Developing States in the Pacific to effectively manage WASH and waste management is constrained by their small size, geographical isolation and expansion, environmental fragility, small and predominantly rural, but rapidly urbanizing populations and limited human and financial resource bases. WASH research, monitoring and global action are still lagging behind the necessary efforts to achieve health-promoting sustainable development

[65]. Fiji, Kiribati and the Solomon Islands, like other Pacific Island Countries, are often not able to provide adequate WASH services to their populations. Besides, these countries are facing significant challenges from a changing climate, and the effect of extreme weather events such as tropical storms, drought, heavy rainfall, and flooding, as well as hardships related to rising sea levels [66].

#### 2.4.1. Research approach and methodology

A Water, Sanitation and Hygiene Sector Monitoring project in Pacific Island Countries (2016–2019), funded by the UNICEF Pacific, aimed at

- a. Assessing the WASH situation through analysis of baseline and census data from rural and urban households, schools and health care facilities.
- b. Strengthening national WASH systems (including monitoring) in Fiji, Kiribati, and the Solomon Islands.

Quantitative baseline and census data of water, sanitation, hygiene and waste management services in households, schools and health care facilities were collected. The data were analyzed and mapped with a focus on uncovering service coverage inequalities and discussed with WASH sector stakeholders at national and international level (government bodies and international and UN organizations working on WASH). The results were then contextualized with rainfall data and extreme weather events through geospatial data analysis (Table 2).

#### 2.4.2. Main findings and contextualization with geography

Inequalities in access to adequate WASH and waste management were widespread and included: urban-rural, provincial and centre-periphery inequalities of drinking water services in households in the Solomon Islands. International inequalities were uncovered as well, with the Solomon Islands lagging behind other Pacific Island Countries in terms of drinking water safety [67]. Inequalities of WASH in schools were also prevalent in the Solomon Islands, with service provision varying not only by island group and province, but also across different school types (i.e. primary schools, high schools) Ministry of Education of the Government of the Solomon Islands and UNICEF Pacific [68]. Inequalities of WASH in healthcare facilities were uncovered as well, varying with geographic division, and across different types of health care facilities (i.e. nursing stations, health centers) in Fiji Ministry of Health and Medical Services of the Government of Fiji, and UNICEF Pacific Water, Sanitation, Hygiene and Waste Management in Health Care Facilities in Fiji Census Report. Prepared by The Water Institute at UNC [69] and Kiribati Ministry of Health and Medical Services of the Government of Kiribati, and UNICEF Pacific Water, Sanitation, Hygiene and Waste Management in Health Care Facilities in Fiji Census Report. Prepared by The Water Institute at UNC [70].

Extreme weather- and climate-related results from the Solomon Islands showed that domestic sanitation infrastructure is highly vulnerable, and little adaptable, under extreme rainfall scenarios – (i) increased rainfall / flooding; and (ii) decreased rainfall / drought - both of which are predicted to increase in frequency and intensity in future, which entails increased health risks [71]. An analysis of disaster preparedness and response in the context of the 2016 Tropical Cyclone Winston - the most severe storm to make landfall in the Southern Hemisphere to date - showed that health care facilities in Fiji are very vulnerable, and not sufficiently prepared to respond to a potentially increased burden of disease during and/or after extreme weather events Ministry of Health and Medical Services of the Government of Fiji, and UNICEF Pacific Water, Sanitation, Hygiene and Waste Management in Health Care Facilities in Fiji Census Report. Prepared by The Water Institute at UNC [69].

#### 2.4.3. Implications for policy and practice

The situation assessment, integration of the WASH, health, education, emergency management, climate change, urban planning and

infrastructure sectors, and resulting evidenced-based contextualized recommendations (i.e. rural and urban sanitation infrastructure adapted to extreme weather events, better emergency response) informed national, regional and global public health, particularly on the SDG 6 (“by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation”) [72].

The collaboration with governmental and non-governmental stakeholders (i.e. Ministry of Health, Ministry of Lands, Ministry of Education, UN-Habitat, UNICEF and WHO) supported planning for the implementation of national and international strategies and policies in economically, socially and environmentally vulnerable small island developing states in the Pacific and progress towards the achievement of SDG targets 6.1) safe drinking water; 6.2) adequate sanitation and hygiene; 6.6) ecosystems; 6a) international cooperation; 6b) stakeholder participation. Moreover, the study informs targets 3.3) on universal health coverage; 11.5) water-related disasters; 13.1) strengthen resilience to natural hazards.

#### 2.5. Understanding the context and obstacles to improvement of WASH among marginalized minority populations

The Roma are Europe’s largest ethnic minority. Their history has been shaped by marginalization, stigmatization and discrimination, and to date, they continue to face prejudice and social exclusion. The Roma population is generally poor, living in crowded and low quality housing in segregated communities on the outskirts of cities, often lacking basic physical infrastructure, including WASH [73,74].

##### 2.5.1. Research approach and methodology

Considering WASH and health-related inequalities in high-income countries, a project on water, sanitation and hygiene among Roma communities (2019–2020) aimed at

- a. Assessing the WASH situation among Roma in Europe.
- b. Identifying WASH-related health risks associated with the WASH situation.
- c. Understanding obstacles to improvement.

A systematic review and meta-analysis of peer-reviewed academic literature on WASH and environmental health risks in Roma households and communities was conducted. The data were analyzed with geospatial methods and contextualized with a focus on uncovering service coverage inequalities and discussed in the cultural context of health (Table 2).

##### 2.5.2. Main findings and contextualization with geography

The study shows that across Europe, Roma communities face more challenges than the majority population with respect to access to WASH, waste management and environmental hygiene, appropriate housing and hygienic living environments. Prominent themes in the literature to describe WASH conditions among European Roma populations include limited access, affordability, and quality of services; self-management of WASH as response and adaptive tactic; unsafe WASH as a reason for eviction; and health risks associated with substandard WASH services. The same factors determining the poor quality of WASH services and environmental health impede their improvement. Major barriers to WASH and healthcare access, affordability and improvement among the Roma exist.

Living marginalized and distant from roads, where public transport is absent, access to healthcare providers to health systems comes with additional hurdles and at a higher cost. Discrimination is still widespread, leading to potential neglect by medical professionals. The low levels of formal education, low socio-economic status and poverty, and limited access to health insurance are adding extra risks and challenges to disease prevention and health promotion. Legal barriers include statelessness, lack of identification documents, illegal tenure and

housing. Social barriers include lack of a formal decision-making structure or social hierarchy, distrust in authorities, reluctance to accept interventions and the variable commitment by Roma community leaders and members. Cultural perceptions of health risks pose another barrier, as they impact on the choice of water source, and the attitude towards disease. Combined with a widespread distrust in non-traditional health practices, in authorities and health professionals, they ultimately impact on health-seeking behaviour. Besides, prejudices towards Roma, lack of political will to engage, political top-down approaches, absence of advocacy on behalf of the Roma, and lack of involvement of the Roma community in planning pose barriers to improvement of both WASH and health. Besides, Roma are not well represented in national statistics, with data collection being complicated not only by difficulties of access and underfunding, but also by distrust and culturally distinctive health beliefs [21].

2.5.3. Implications for policy and practice

The context of WASH among Roma is challenging and complex and demonstrates not only the urgent need for action for Roma communities in particular, but may have broader applicability to ethnic and social minorities in other parts of the world [21]. The success of interventions depends on the buy-in from decision-makers and good relations between natural leaders of ethnic minority communities and “outsiders” [75], and on the involvement, support, commitment and participation of Roma community members [74].

Future research to overcome obstacles to improvement needs to be inclusive, and involve community members as key informants, with their participation enhancing the reliability of data, contributing to

social justice and solidarity, disseminating information, contributing to feasible recommendations and implementation of interventions [21].

Findings of this research shall inform efforts to achieve SDG targets 3.3) tuberculosis, hepatitis, water-borne diseases and other communicable diseases; 6.1) safe drinking water; 6.2) adequate sanitation and hygiene; 6.3) water quality and wastewater; 10.2) social, economic and political inclusion of all.






3. Triangulation and contextualization

Global environmental change, increasingly frequent and unpredictable extreme weather events, water scarcity, food insecurity, conflict, migration, urbanization, and other processes have been impacting the interface of water security and global health at global, regional, national, and local levels over the past decades. The contexts are complex, and this will further challenge practice and policy making—not only in low- and middle-income countries, but also among minority populations and low socio-economic and other vulnerable groups in high-income countries.

The presented studies sought to understand drivers, recommend actionable contextualized measures, direct practice and interventions and inform policy-making in the context of water security [13] and global health, by drawing on medical geography approaches. They were conducted in very diverse geographical, climatological and sociocultural settings and had different objectives (Table 3), but used similar research approaches that allowed to consider the settings as complex systems in their entirety.

Cross-cutting topics and contextualizations, beyond water security

**Table 3**  
Holistic, interdisciplinary, mixed methods approaches to contextualize water security and human health research: contextualization of included case studies.

	Wetland in Kenya	Protracted emergency in Nigeria	Floodplain in Namibia	Small Island Developing States in Pacific	Underserved minority in Europe
					
Context	Assessing health risks	Directing health interventions	Understanding health sector response	Strengthening WASH and health systems	Obstacles to improvements in WASH
Involvement	Government bodies	Government bodies, international organizations	Government bodies, international organizations	Government bodies, international organizations	NA (literature review)
Highlights	Wetland users as key informants to understand the situation in the community. Risk perception studies and resulting recommendations as supportive decision-making tool.	Identification of measures and recommendations for interventions. Roadmap to direct future humanitarian practice, health interventions and policies.	Identification of measures to reduce negative impact that floods cause for care provision, future continuation of care during flooding and improved disaster response.	Monitoring of national WASH coverage. Support of planning for the implementation of national and international strategies, policies and SDG 6.	Socio-cultural context as major barrier to service provision. Identification of need to involve representatives of the ethnic minority in planning and programming.
Applicability in policy and practice	Understand drivers of complex situations; recommend actionable contextualized measures; direct practice and interventions; inform policy-making	Understand drivers of complex situations; recommend actionable contextualized measures; direct practice and interventions	Understand drivers of complex situations; recommend actionable contextualized measures; direct practice and interventions; inform policy-making	Understand drivers of complex situations; recommend actionable contextualized measures; direct practice and interventions; inform policy-making	Understand drivers of complex situations; recommend actionable contextualized measures; inform policy-making
Link to SDG	Targets 3.3) malaria, neglected tropical diseases, water-borne diseases and other communicable diseases, 6.1) safe drinking water, 6.2) adequate sanitation and hygiene, 6.4) water use and scarcity, 6.5) water resources management and 6.6) ecosystems.	Targets 3.8) universal health coverage, 6.4) water use and scarcity, 6a) international cooperation and 6b) stakeholder participation, 16.1) reduce all forms of violence and related deaths.	Targets 3.3) AIDS, 3.8) universal health coverage, 11.5) water-related disaster.	Targets 3.8) universal health coverage, 6.1) safe drinking water, 6.2) adequate sanitation and hygiene, 6.6) ecosystems, 6a) international cooperation and 6b) stakeholder participation, 11.5) water-related disaster, 13.1) strengthen resilience to natural hazards.	Targets 3.3) tuberculosis, hepatitis, water-borne diseases and other communicable diseases, 6.1) safe drinking water, 6.2) adequate sanitation and hygiene, 6.3) water quality and wastewater, 10.2) social, economic and political inclusion of all.

This table is based on case studies from Kenya [54–59], Nigeria [61]; Namibia [64]; Fiji, Kiribati and the Solomon Islands [67–71] and Europe [21].



and global health, including climate- and weather-related extreme events, inequality, risk perceptions, behaviour, and the cultural context of water and health implications could only be identified based on the broad approach, variety of methods, scales, and respondents used in the presented studies:

### 3.1. Extreme weather events

Extreme weather events such as major floods, droughts and tropical cyclones, may have detrimental effects on the overall health, and security of population groups, and on healthcare and WASH infrastructure.

Evidence from the Solomon Islands showed that domestic sanitation infrastructure is highly vulnerable, and little adaptable, under extreme rainfall scenarios, drought and flooding, leading to overflow of sewers, and non-usability of sanitation facilities. This entails increased health risks [71]. In Nigeria, drought and water scarcity exacerbate health challenges that internally displaced people in a humanitarian protracted crisis are facing, putting an extra strain on overburdened (or even inexistent) health services [61]. Health care facilities in Fiji are very vulnerable towards tropical cyclones, and also, they are not prepared to respond to the increased disease burden that cyclones cause Ministry of Health and Medical Services of the Government of Fiji, and UNICEF Pacific Water, Sanitation, Hygiene and Waste Management in Health Care Facilities in Fiji Census Report. Prepared by The Water Institute at UNC [69]. In Northern Namibia, where extensive seasonal flooding is prevalent, flood-related breakdown of health and WASH infrastructure lead to increased health risks and reduced treatment opportunities for vulnerable populations such as people living with HIV and AIDS [64].

Thus, while increasing the risk of exposure towards water-related infectious diseases, and accelerating the progression of disease, extreme weather events at the same time hamper access to healthcare facilities and treatment and thus, the opportunity to receive care, creating a dual health risk.

### 3.2. Inequality

Inequality persists in terms of access to safe water, sanitation, hygiene and healthcare not only between continents, regions and countries, but also at a sub-national level. Evidence from the Solomon Islands shows that at a household level, drinking water access differs according to province, between centre and periphery and between urban and rural areas, with central provinces using piped water and remote provinces use rain- and surface water as main source. Drinking water inequality is also related to precipitation [67]. Inequalities also persist among marginalized minority populations, as found among Roma communities in Europe. Roma populations living in informal settlements distant from roads, cities and infrastructure also have unequal access to safe WASH. WASH inequalities in these communities persist at local, national and regional levels [21].

At a non-household level, WASH inequalities in healthcare facilities were found to be related to geography too, differing according to region and medical division in Fiji and Kiribati. Likewise, systemic inequalities at non-household level persist in different types of healthcare facilities [69,70], and in different types of schools in the Solomon Islands [68].

Besides, inequalities persist in terms of health promotion and exposures to disease, based on location, proximity to and interaction with water body, e.g. through occupation as found in Kenya, where farmers who live near wetlands and closely interact with water are at higher risk of contracting malaria, and where pastoralists who live distant from the wetland in drier environments are at higher risk of contracting trachoma [55,57]. Finally, inequalities in terms of disease exposure, access to healthcare and health-seeking behaviour are prevalent among ethnic minorities as compared to majority populations, as found among Roma communities in Europe [21] and among nomadic pastoralists in Kenya [58].

### 3.3. Cultural context

Cultural contexts may determine health-related perceptions, behaviours, and as a consequence, health promotion and disease exposure. Convictions, health beliefs, social stigma, and (mis) conceptions about health and healthcare can be decisive factors for health-seeking behaviour, treatment and cure.

As found in a Kenyan wetland, the level of health risk perception is high, with exposure to water-related infectious diseases understood as being driven by users' physical contact to water during wetland use, characteristics of pathogens and vectors of disease, both in domestic and occupational environments. Different user groups, i.e. farmers and nomadic pastoralists, perceive risks differently and different (occupational) risks are attributed to different groups. While many perceptions well reflect the real causes of disease, numerous misconceived health beliefs are manifested especially among the pastoral nomads. Such include malaria being caused by rain, pesticides and elephants or diseases caused by witchcraft [57]. Some Roma communities in Europe, believing that this practice increases water safety, may use salt or lime to treat drinking water from personal wells despite the lack of evidence of this practice removing contaminants and pathogens from the water [21].

In terms of health-seeking, the cultural context matters as well. Roma populations, for example, commonly have a very distinct understanding of the meaning of health and health risks and therefore also perform different health-related behaviours as compared to the majority population. A spiritual base exists for certain kinds of illness and belief in traditional curative remedies such as the power of spittle to treat wounds. Perception, acceptance or rejection of certain diseases may determine the willingness to seek medical help or support from the communities, affecting rehabilitation [21]. In Kenya, some illnesses are simply perceived as 'not for hospital', are treated by traditional healers or herbalists, by self-treatment or not treated at all [55]. Thus, while the overall risk perception may be high and accurate, this does not necessarily allow for assumptions about the local ways to deal with ill-health and health-seeking [58].

### 3.4. Policy, practice and triangulation

Based on all studies presented in this paper, policy and practice was informed adopting holistic and interdisciplinary approaches (combinations of risk assessments, syndromic surveillance, behavioural studies, perception studies), using mixed methods (literature review, grounded theory, quantitative survey, observational spot checks, qualitative interviews, focus group discussions, stakeholder meetings, mapping), different perspectives within and outside of the community (different sociocultural groups, stakeholders, and community versus health care providers), at different implementation and geographical levels (local, regional, national, international).

In the presented studies, the use of a single method or assessment would have been insufficient to draw a comprehensive picture and thus to create an understanding of the situation and its implications. The studies set a major focus on triangulation of the results, which allowed to fully display the context and complexity by using and discussing results from different data sources against each other.

## 4. Takeaways

Diverse actors see water security-related global health challenges from different and partly even contradicting perspectives. It is therefore vital to look at challenges from different angles and at the challenge under investigation from a holistic perspective. Using the 2030 Agenda for Sustainable Development, its sustainable development goals and targets [48], as well as Gleick and Iceland's water and security pathway classification (diminished water supply or quality, increased water demand, and extreme flood events) [13] as a frame, this paper with case

studies from the South Pacific, wetlands, floodplains and a protracted emergency setting in Sub-Saharan Africa, and living environments of Roma communities in Europe, medical geography offers great potential in contributing to achieve the goals related to water security and global health.

Medical geography can bridge different health and health system contexts; local, regional, national and global perspectives and priorities; and research, policy and field practice, involving the target population (s) as key informants. It can assist policy-makers and practitioners to understand the key drivers, barriers and bottlenecks in complex situations; recommend actionable and contextualized measures to address these challenges; direct programming and interventions; and inform policy-making to tackle and solve these challenges.

Future research relating to water security and global health could consider also water-society interactions, e.g. the hydrosocial cycle [76]. Future research could apply and integrate remote sensing, earth observation, big data and artificial intelligence, besides the presented mix of quantitative and qualitative methods with geospatial analysis: these and other technologies bear much potential to inform water security and global health-related understanding and decision-making.

### Declaration of Competing Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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