



Water insecurity and urban poverty in the Global South: Implications for health and human biology

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Abstract

Objectives: Over half of the world's population (4 billion people) experience severe water scarcity at least one month per year, while half a billion people experience severe water scarcity throughout the year. Despite progress from national and global interventions, a staggering proportion of the Global South remains water insecure. Rapid urban growth and associated demographic changes, climate change, and governance failure have also fostered the growth and expansion of urban informal settlements and slums where widespread poverty and environmental hazards exacerbate the impact of water insecurity on health. This article reflects on the interactions between water insecurity and urban poverty in the Global South across four categories of health outcomes: gastrointestinal diseases, mosquito-borne diseases, injuries, and mental illness. These examples highlight the mechanisms through which urban poverty exacerbates the adverse health effects of water insecurity.

Methods: The four selected health outcomes were chosen a priori to represent two communicable conditions with well-developed literatures, and two non-communicable conditions with newer literatures that have emerged over the last decade. We conducted a narrative literature review of scholarly and gray literature appearing between January 2000 and April 2019 using several online scholarly databases.

Results: Gastrointestinal diseases, mosquito-borne diseases, injuries, and mental illness all exemplified the relationship between water insecurity and urban poverty through human biological pathways. For each of the four health categories, we identified frontiers for human biology research contributions to the water-poverty-health nexus.

Conclusions: We discuss our findings in the context of three crosscutting themes that merit innovative research approaches: stressor interactions and trade-offs, exposure thresholds, and intervention efficacy. We reiterate that the global burden of disease associated with water insecurity cannot be addressed in isolation from efforts to alleviate extreme poverty.

1 | INTRODUCTION

Water insecurity, defined as lack of access to water or limited ability to secure water that is safe, affordable, and

socially acceptable, is a significant threat to the health and overall well-being of humans. Yet globally, 4 billion people experience severe water scarcity at least one month per year, and half a billion people experience



severe water scarcity throughout the year (Mekonnen & Hoekstra, 2016). Despite two decades of global and national water policy interventions, including the Millennium Development Goals (MDG) (2000-2015) and the Sustainable Development Goals (SDG) (2015-2030), over 1.8 billion people, most of them in the Global South, are without reliable access to safe drinking water (Onda, LoBuglio, & Bartram, 2012). Unsafe water remains a significant contributor to the global burden of disease and mortality especially in low and middle-income countries (Clasen et al., 2014; Onda et al., 2012; Prüss-Ustün et al., 2014). In 2016, diarrhea alone accounted for 1.4 million deaths, out of which 65% was due to poor drinking water and sanitation (Prüss-Ustün et al., 2019). In the poorest regions of the world, unsafe water accounts for nearly 90% of all diarrheal diseases (Wolf et al. 2014).

In the Global South, population growth and rapid urbanization exacerbate the effects of water insecurity on health. Between 1975 and 2010, the urban population in the Global South tripled, growing by 2 billion people (Satterthwaite & Mitlin, 2012). Most of this growth occurred in Sub-Saharan Africa and Asia where water insecurity was already shaping lives and inhibiting development. Rapid urbanization in these regions has increased urban poverty and inequality and led to the creation and expansion of informal settlements and slums with precarious conditions (Lucci, Bhatkal, & Khan, 2018; Satterthwaite & Mitlin, 2012). The UN Settlements Program (UN-Habitat) predicts that by 2050, nearly 3 billion people (over 60% of the urban population in developing countries) will be living in slums, almost tripling the current number of about 1 billion (UN Habitat, 2014).

Although 85% of the world's urban population used safely managed drinking water services, as defined by the Joint Monitoring Programme drinking water ladder, there is significant regional variation, with the rate falling to 50% for Sub-Saharan Africa's urban areas (WHO, 2009). Many of the urban poor in the Global South rely on water sources outside their premises that are prone to contamination, especially during transport (Wright, Gundry, & Conroy, 2004). These sources include public standpipes, boreholes, sachet water, tanker-truck services, and water from small-scale vendors (Kjellén & McGranahan, 2006; Stoler, 2017; Dos Santos et al., 2017), and are often insufficient, shared by many households, unsafe, or costly (Dos Santos, Ouédraogo, & Soura, 2015; Majuru, Suhrcke, & Hunter, 2016; Price, Adams, & Quilliam, 2019). Even when available, improved water sources often run intermittently or require long queuing times, thus forcing households to supplement with unsafe alternatives, a trend observed across Africa (eg, Adams, 2018b; Dagdeviren & Robertson, 2011), Latin America (eg, Cifuentes & Rodriguez, 2005; Wutich,

Beresford, & Carvajal, 2016), and Asia (eg, Cheng, 2014; Raina, Zhao, Wu, Kunwar, & Whittington, 2019; Truelove, 2019).

Gaps in service delivery and public water utilities' reluctance to serve informal urban areas have created "water mafias" who exploit residents. Accounts from Bangalore show that water mafias have intricate connections to the state, and state water employees often participate in water mafia operations (Ranganathan, 2014). Similar experiences of water mafias have been recorded in Dhaka (Haque, 2019), Mumbai (Button, 2017), and Jordan (Mustafa & Talozzi, 2018). These challenges exemplify governance failure, which involves all the institutional, governance, and infrastructural weaknesses behind poor water access in the Global South (Adams, Sambu, & Smiley, 2019; Bakker, Kooy, Shofiani, & Martijn, 2008; Kooy, 2014; Truelove, 2019). Governance failure occurs when "institutional dimensions of water management and decision-making do not effectively take into accounts the needs of poor households, creating disincentives for the water supply utility to connect poor households and/or for poor households to connect to the network" (Bakker et al., 2008, p. 1894).

Although widening poverty from rapid demographic shifts interacts with these water insecurities to compromise the health of the urban poor, the exact mechanisms have not been fully understood. There are abundant literatures on poor water access, health outcomes, and urban poverty, but there is no systematic documentation of how the three processes interact. This article reflects on the interactions between water insecurity, urban poverty, and adverse health outcomes in the Global South. It highlights some of the mechanisms through which the interactions between poverty and water insecurity compromise health in urban areas and the role diverse social and environmental pathways play.

We focus on four health outcomes, two of which are communicable conditions that are relatively well-characterized with respect to the water-health literature (*gastrointestinal diseases* and *mosquito-borne illnesses*) and two more recent and rapidly growing areas of water-health inquiry (*injuries* and *psychosocial and mental illnesses*). These outcomes are by no means the only, or necessarily most urgent, health implications of water insecurity. However, they are important examples from our own fieldwork and are supported by a literature base that illustrates the pathways by which urban poverty exacerbates water insecurity and ultimately adversely affects health. In the following sections, we define key concepts and theoretical foundations, describe briefly the methods used in our narrative review, and discuss four health outcomes as examples of the mechanisms through which urban poverty shapes water insecurity and



ultimately human health. We conclude with new frontiers for human biology research contributions to the water-poverty-health nexus.

2 | WATER INSECURITY, URBAN POVERTY, AND HEALTH IN THE GLOBAL SOUTH

Our discussion is grounded in a relational approach to water insecurity. A relational understanding of water insecurity accounts for the role of broader social and political relations that enable or constrain access to water. It underscores the different ways in which water insecurity is experienced beyond water itself, notably how access to and exclusion from water are shaped by political and social relations at different scales (Jepson et al., 2017). A relational analytical lens recognizes that the interactions between water access, poverty, and health are not due to water's physical nature alone. It is based on the notion that the ability to secure safe, affordable and socially acceptable water and the capacity to cope with everyday water challenges are both profoundly shaped by social relations (eg, age, gender, ethnicity) and power (O'Reilly, Halvorson, Sultana, & Laurie, 2009; Sultana, 2009). Such relational framing is particularly relevant for understanding water and health intersections in vulnerable urban areas of the Global South where livelihoods and capabilities to function are easily disrupted through different society-water relations.

Likewise, we conceptualize urban poverty in terms of both material and nonmaterial deprivation, inspired by Sen's human capabilities approach to poverty (Sen, 1999) and emerging scholarship on relational poverty (Elwood, Lawson, & Sheppard, 2017; Mosse, 2010). The traditional notion of poverty based strictly on income has been widely criticized for being inaccurate and overlooking the institutional and social contexts within which poverty emerges and thrives (Anand & Sen, 1997). A "capabilities view of poverty" considers that the capacity of people to flourish, cope with everyday stresses, function, and achieve what they consider valuable is a function of their social environment (Sen, 1999). Comparably, the "relational poverty" concept defines poverty as a product of human relationships, institutions, power relations, and other social conditions, and views political economic exploitation, dispossession, and lack of capability as central features of poverty (Elwood et al., 2017). Rather than simply define poverty as a state of deprivation of income and entitlements, and therefore static, it directs attention to the historical economic, political, and social relations that produce poverty and enable its endurance. It is rooted in the idea

that poverty is ultimately an institutionalized process involving a set of relations between the wealthy and the less affluent as opposed to merely a condition of lack and vulnerability (Mosse, 2010).

Building on these conceptual foundations, our aim is to highlight how the urban socio-environmental context influences the relationship between water insecurity and health. Urban environments in the Global South can be hazardous, and they often impose significant stress on health irrespective of one's income status. The ecology of most of these urban environments is such that disease pathogens can spread rapidly (Figure 1) (Adams, Price, & Stoler, 2019). The quality of water can deteriorate from the source, via transportation, storage, and handling at the point of use (Boateng, Tia-Adjei, & Adams, 2013; Copeland et al., 2009; Shields, Bain, Cronk, Wright, & Bartram, 2015). The dense and overcrowded nature of these urban environments coupled with poor sanitation, open sewers, and pit latrines create multiple exposure pathways. Pit latrines routinely overflow and release of fecal sludge, contaminating soil, surface and ground water sources particularly during the rainy season (Carter, 2013; Rusca, Alda-Vidal, Hordijk, & Kral, 2017). Environmental conditions may also expose households to the risk of injuries during water fetching while the social environment, known for exclusion, heterogeneous composition, and multiple stresses, may also complicate the impact water insecurity on psychosocial health.

3 | METHODS

We reviewed four categories of adverse health conditions that exemplify the interaction between water insecurity, poverty, and health. We made the a priori selections of gastrointestinal diseases, mosquito-borne diseases, injuries, and mental illness based on our knowledge of these burdens from our own fieldwork, but also based on our general knowledge of their respective related scholarly literature. Gastrointestinal and mosquito-borne diseases are relatively well-characterized, communicable health conditions with rich scholarly literatures, while injuries and mental illness are noncommunicable conditions that have largely only received significant scholarly attention over the last decade. But given the breadth of related literature across these four health issues, we opted for a narrative review format that would allow us to search more broadly across interdisciplinary trends in water, poverty, and the chosen health issues with an urban context. Systematic reviews tend to be more useful when there is a narrow research focus, typically of quantitative data (Collins & Fauser, 2005; Ferrari, 2015), and this was not our objective.

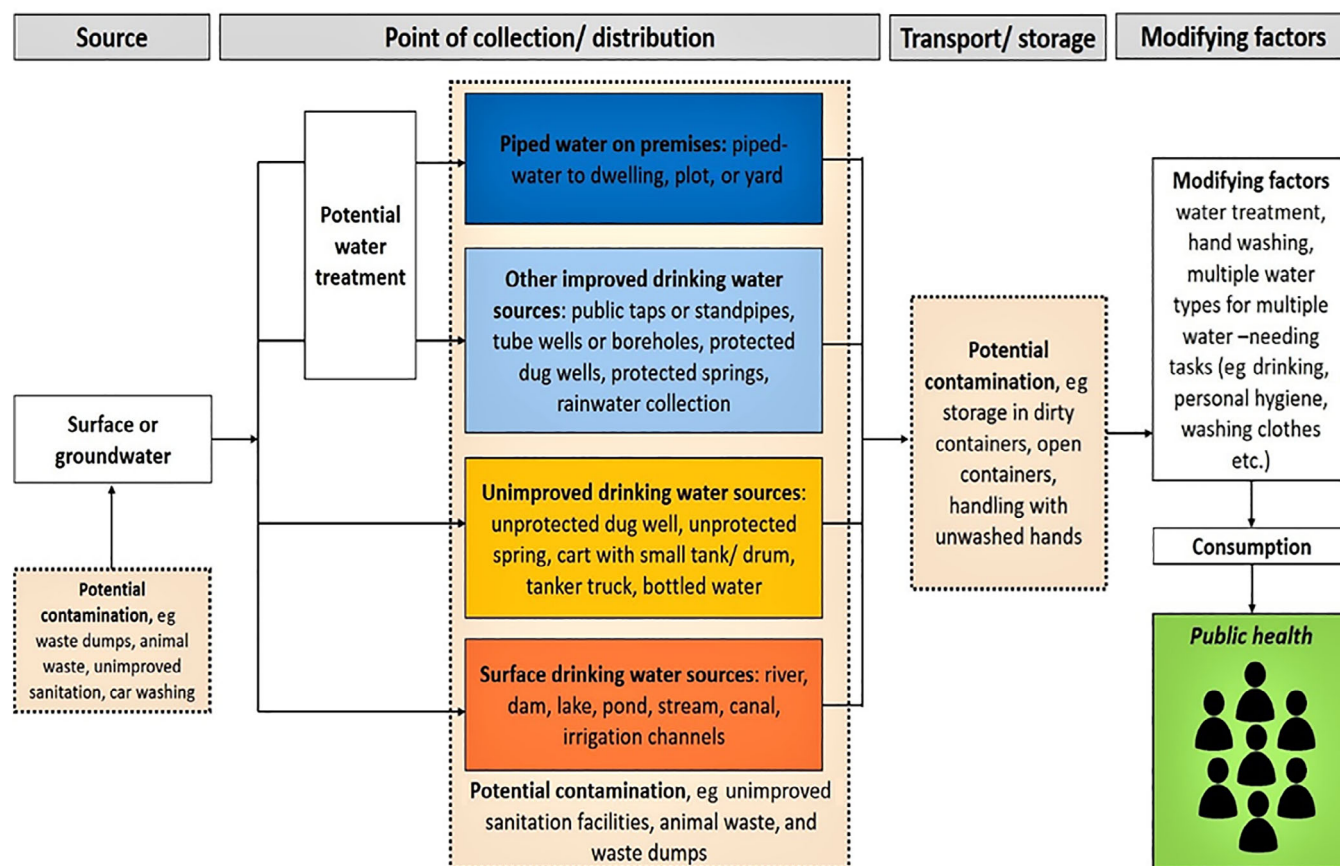


FIGURE 1 Water contamination pathways in urban slums (Adams, Price, & Stoler, 2019)

We reviewed published and gray literature appearing from January 1, 2000 to April 30, 2019 through structured searches in Scopus, PubMed, and Google Scholar using select key words in combination with *water*, *insecurity*, *urban*, and *poverty*: gastrointestinal, diarrhea*, mosquito*, container, injury, injuries, carrying, carriage, mental health, mental illness, and psychosocial. We excluded earlier literature in favor of recent literature that reflects current research trends in poverty, water, and health studies, and only reviewed English language abstracts and documents. An exhaustive review of gastrointestinal diseases, mosquito-borne diseases, injuries, and mental illness was well beyond the scope of this article.

4 | RESULTS

4.1 | Water insecurity, urban poverty, and gastrointestinal diseases

Gastrointestinal diseases such as diarrhea and cholera are critical causes of morbidity and mortality in the Global South. Children under the age of five in developing countries are particularly more vulnerable to and

likely to die from enteric infections (Adane, Mengistie, Kloos, Medhin, & Mulat, 2017; Kalakheti, Panthee, & Jain, 2016; Melo et al., 2008). The World Health Organization estimates that diarrhea is the second leading cause of death among children under 5 years, causing over 1.5 million childhood mortality cases annually (WHO, 2009). Diarrhea may also expose children in slums to stunting and cognitive impairments (Budge, Parker, Hutchings, & Garbutt, 2019; Otsuka, Agestika, Sintawardani, & Yamauchi, 2019; Paudel, Pradhan, Wagle, Pahari, & Onta, 2012). In the informal settlements of Nairobi, Kenya, infants and children under 5 years bore four times the mortality associated with diarrhea compared to the adult population (Kyobutungi, Ziraba, Ezech, & Yé, 2008).

While urban areas and informal settlements in the Global South are ideal spaces for gastrointestinal disease infection due to open drainage systems, weak sanitation infrastructure, flooding, and leaking sewage systems, poverty, water handling, and storage expose already vulnerable households to *Escherichia coli* (Oswald et al., 2007). It is common for poor, large households to share drinking cups, buckets, and cooking utensils. In doing so, households inadvertently mix water from different

sources and spread fecal coliforms via cross contamination. Even when water is clean from source, or boiled before storage, shared drinking cups enable contamination (Oswald et al., 2007). Poor households who cannot afford closed containers opt for the cheaper open containers that can expose water to other environmental contaminants, such as chemical particulates and fecal dust. Some use wooden planks to cover water storage containers or, for lack of space, choose to store containers in unhygienic open environments (Figure 2), while others avoid boiling unsafe water because they do not have surplus containers. Households unable to buy enough water for household use may intentionally avoid rinsing containers (Boakye-Ansah, Ferrero, Rusca, & van der Zaag, 2016). Poor households face tougher choices between safe, costly water sources vs cheaper, unsafe sources. Households unable to afford multiple containers may not separate safe and unsafe sources. Lack of adequate storage containers can also create feelings of exclusion among the poor in cases where lack of storage containers signifies low social status, inequality, and poverty (Keough & Youngstedt, 2014). Poorer households in urban slums may also opt to reside in more hazardous environments even if they are aware of the environmental and safety concerns. In the urban slums of Salvador, Brazil, *Leptospirosis* infections remain highest among the poorest urban population, most of whom lived close to open sewers (Felzemburgh et al., 2014).



FIGURE 2 Open water storage containers in Nima, Accra

4.2 | Water insecurity, urban poverty, and mosquito-borne diseases

The mechanisms by which water insecurity and urban poverty foment mosquito-borne disease transmission are widely accepted (Knudsen & Slooff, 1992). Unreliable water supplies often mean that households store water, whether in containers for household domestic use and drinking, or in small canals or furrows for livestock and urban agriculture. Both adaptations can inadvertently amplify mosquito populations of public health importance. Unsafe household water storage—the same practices that enable cross contamination and increase the risk of gastrointestinal disease—may allow *Aedes* mosquitoes to lay eggs in water-holding containers. If containers are not changed or washed regularly, *Aedes* mosquitoes can breed quickly and transmit several viral fevers (especially yellow fever, dengue, chikungunya, and Zika) (eg, Kaur et al., 2008; Trewin, Kay, Darbro, & Hurst, 2013) and forms of encephalitis. The maintenance of small bodies of surface water for irrigated urban agriculture or livestock can also provide ideal breeding ground for *Anopheles* mosquitoes that transmit malaria, thus introducing a traditionally rural risk factor into urban neighborhoods where residents are less likely to have developed immunological tolerance of the malaria parasite (Donnelly et al., 2005; Stoler, Weeks, Getis, & Hill, 2009).

The burden of urban poverty interacts with water storage needs in multiple ways to increase the risk of human disease. Poor urban households often keep many water-holding containers around the premises as a buffer against seasonal scarcity or other shortfalls. These communities also often have limited options for solid waste removal and are often forced to dump household trash. Rain will collect in small containers or vessels—whether trash or purposefully saved—and these undisturbed containers can support explosive disease outbreaks (Krystosik et al., 2017). Policies to improve nutrition and alleviate poverty in low-income neighborhoods of the Global South have also encouraged urban agriculture expansion (Smit, Nasr, & Ratta, 1996), with water insecurity driving further investment in water capture, and urban malaria viewed as an unintended consequence. Social, institutional, and environmental factors also interact with low community awareness of vector borne disease ecology in poor neighborhoods and contribute to frequent misdiagnosis of infections, which impedes proper health care (Jankowska, Stoler, Ofiesh, Rain, & Weeks, 2015; Stoler & Awandare, 2016). All of these processes, of course, are exacerbated by climate change, which is actively altering the interactions between weather, water and food availability, and vectors around the world (Campbell et al., 2015; Tonnang, Kangalawe, & Yanda, 2010).

Although the pathways between water insecurity, urban poverty, and mosquito-borne diseases are relatively clear, we still have much to learn about pathogenesis. The spread and establishment of new viral fevers over the last few years, such as chikungunya and Zika, present potentially important cross-reactivity with other endemic viral diseases such as dengue. For example, we know antibody dependent enhancement exists between some viruses, such as dengue and Zika (Dejnirattisai et al., 2016), but we have not fully characterized all of these relationships or the implications for vector control funding and vaccine programs. As introduced pathogens become endemic to new regions, their relationship to water insecurity will evolve as well.

4.3 | Water insecurity, urban poverty, and injuries

Water fetching in most places in the Global South is a physical task entailing walking and carrying of heavy containers. Households make multiple trips to water sources to meet daily water needs (Sorenson, Morssink, & Campos, 2011). The drudgery of water collection by women, girls, and children who carry heavy containers of water either on their head or back, or by hand, exerts significant strain on their physical health. Falls and slips are common effects of carrying as women carry water over steep slopes, uneven terrains, and slippery landscapes. A rapidly growing body of research is beginning to show that water carriage is significantly associated with injury or risk of injury, pain, fatigue, and violence against women engaged in water fetching (Geere, Cortobius, Geere, Hammer, & Hunter, 2018). In low-income countries, water carriage predisposes people to musculoskeletal disorders, including pain in the hands, back, and spinal regions and undermines general well-being (Geere et al., 2018). Other studies have reported chest pain, fatigue, and headache among women and girls who carry water regularly (Asaba, Fagan, Kabonesa, & Mugumya, 2013).

Water fetching by the urban poor often involves navigating complex socio-environmental conditions with significant physical strain and can consume significant time via multiple rounds of fetching from different water sources. To guard against intermittent supply, some women carry and transport multiple heavy containers of water, sometimes in a wheelbarrow (Figure 3) (Porter et al., 2013). Unlike in rural areas, even short walking distances in urban environments may entail complex and hilly terrains with obstacles and uneven elevation that can cause falls during heavy rainfall episodes (Smiley, Curtis, & Kiwango, 2017). Impediments along water fetching routes in poor urban areas can easily lead to



FIGURE 3 Women hauling water in Lilongwe, Malawi

slips and falls. Stagnant pools, uneven terrains, flooded areas, open challenges, and sewage from pit latrines can lead to injuries as are steep terrains with varying elevations (Smiley et al., 2017). Water fetchers in risky urban environments have encountered open drains, stacks of debris, and discarded old materials that can cause injuries (Smiley et al., 2017). Women may carry infants on their back while carrying water through these complex spaces (Figure 3), increasing vulnerability to pain, disability, and other musculoskeletal disorders (Geere, Bartram, et al., 2018).

4.4 | Water insecurity, urban poverty, and psychosocial health

There is growing evidence that water insecurity is linked to psychosocial disorders (Aihara, Shrestha, Kazama, & Nishida, 2015; Bisung & Elliott, 2017b; Collins et al., 2018; Stevenson et al., 2012). Water insecurity leads to emotional stress, anger, anxiety, shame and stigma, social

exclusion, and threatens mental health particularly among women (Bisung & Elliott, 2017b; Hadley & Wutich, 2009; Tutu & Stoler, 2016; Wutich & Ragsdale, 2008). The psychosocial effects of water insecurity are gendered, with women bearing a disproportionately higher burden (Cooper-Vince et al., 2018; Stevenson et al., 2012). In Ethiopia, women who were water insecure were more likely to report mental health disorders (Stevenson et al., 2012). In a study in Kenya using hair cortisol as a biomarker for stress, concentrations were higher among women who reported safety concerns during water collection or while performing sanitation tasks (Henley et al., 2014). In her analysis of water and arsenic contamination in Bangladesh, Farhana Sultana also demonstrated the different ways through which women's emotions and sense of suffering matter in their everyday struggles to cope with, respond to, and relate to water; she points to how emotional expressions of worry, frustration, anxiety, and distress become mundane aspects of how women secure water (Sultana, 2011). Together, these studies demonstrate that water insecurity in various forms is a significant hindrance to psychosocial well-being. They reinforce the need to understand mechanisms linking water insecurity experiences with psychosocial disorders and associated physiological consequences.

While the mechanisms through which urban poverty worsens the psychosocial effects of water insecurity remain poorly understood, the social and physical environment as well as everyday negotiations for water in informal settlements and slums provide some clues. Control of water by water mafias or landlords can create disruptions in everyday livelihoods and feelings of exclusion and disenfranchisement, particularly where poor households perceive discrimination by affluent neighbors with better water access (Tutu & Stoler, 2016). In an example from urban Odisha, India, negotiating access to shared public water sources was a constant source of stress for poor households (Sahoo et al., 2015). Water rationing and uncertainties over water supply times may engender feelings of anxiety. Women's inability to perform these tasks leads to feelings of inadequacy, shame, fear, worry, and anxiety that ultimately leads to poor mental health (Hulland et al., 2015; Workman & Ureksoy, 2017). When women are incapable of performing duties that are traditionally important and expected, such as keeping houses clean for visitors, helping their families to maintain proper hygiene, and ensuring that their families are clean and able to participate in public functions, feelings of anxiety and mental illnesses may develop (Stevenson et al., 2012). For example, women in urban areas of Odisha, noted that the most stressful aspect of their sanitation experiences was the need to carry water every day, sometimes getting wet on rainy days and walking

through mud (Hulland et al., 2015). The same study found that defecation, menstruation, and cleaning duties were constant sources of stress related to water and sanitation and insecurity (Hulland et al., 2015). Similarly, in Haiti, household water insecurity was both directly and indirectly (through food insecurity and sanitation) associated with anxiety and depression (Brewis, Choudhary, & Wutich, 2019a). Intermittent water supply, high cost of water, uncertain delivery of water by vendors, and other water insecurities can be particularly burdensome to women who manage the household and lead to anxiety, stress and mental disorders (Bisung & Elliott, 2017b; Wutich & Ragsdale, 2008).

Ethnically heterogeneous environments, weak social cohesion, and exclusion can exacerbate the psychosocial effects of water insecurity on the urban poor, in contrast with globalization-induced pathways between water insecurity and mental ill health that have been observed in rural communities (eg, Tallman, 2019). Poor urban communities are more likely to include migrants and diverse nuclear families with weaker ties. Social support networks enjoyed in rural areas may be harder to recreate in dense, ethnically diverse urban environments, and this weakens household resilience to water insecurity and its psychosocial effects. In western Kenya, social relationships were central to the capacity of families to cope with the stress and anxiety associated with water insecurity (Bisung & Elliott, 2017a). A recent study in the urban slums of Accra, Ghana, shows that strong social relations and community social capital moderate the effects of stress on mental health (Greif & Dodoo, 2015).

5 | CONCLUSION AND FUTURE RESEARCH FRONTIERS

As the Global South continues to experience rapid population growth and urbanization, poverty and inequality aggravate the impact of water insecurity on the health and well-being of vulnerable urban residents. Water insecurity is a crosscutting issue that intersects with many different biological mechanisms in high-poverty settings. The use of unsafe water sources, numerous contamination pathways, dangerous water fetching conditions, and other household dynamics expose the urban poor to adverse health effects such as gastrointestinal illnesses, mosquito-borne diseases, injuries, and psychosocial disorders. To achieve SDG 6—to ensure the availability and sustainable management of water and sanitation for all—and address the global burden of disease associated with water insecurity, global and national interventions must integrate SDG 6 efforts with SDG 1 activities to end poverty.



Historically, water-health interventions have been based almost entirely on traditional indicators of water access such as availability, distance, price, and quality. But growing evidence suggests that these metrics do not fully explain water insecurity experiences (Lucci et al., 2018; Smiley, 2017; Wutich et al., 2017), as newer ways of conceptualizing water insecurity emphasize how socio-cultural, political, power relations and other dynamics shape water insecurity (Jepson et al., 2017). Such new ways of thinking open up possibilities for us to understand water insecurity's influence on poor health as cross-cutting within particular social and environmental contexts. Our review uncovered at least three key areas at the intersection of water insecurity, urban poverty, and poor health that merit more research: *stressor interactions and trade-offs*, *exposure thresholds*, and *intervention efficacy*.

The urban poor do not experience water insecurity in isolation from other stressors, such as climate change; food, energy, and housing insecurity; and socio-political exclusion (Rashid, Gani, & Sarker, 2013; Roy, Cawood, Hordijk, & Hulme, D. (Eds.), 2016). While ample evidence shows that the health of the urban poor is simultaneously shaped by a wide range of physical, economic, social, and political factors (Cairncross, Hardoy, & Satterthwaite, 1990; Satterthwaite & Mitlin, 2012), how do these factors influence water insecurity, and in turn, how does water insecurity interact with them to compromise health? Particularly in urban slums, everyday stressors may also be a function of governance and power relations at multiple scales. These potential interactions call for syndemic frameworks that can tease out the differential and multiplicative effects of water insecurity, poverty, and social and environmental factors on the urban poor. Recent evidence shows linkages between water insecurity and food insecurity (Brewis & Workman, 2019), and with HIV and everyday vulnerabilities, and increased anxiety and depression (Workman & Ureksoy, 2017). Recent work has also observed gendered effects between low water access and high blood pressure (Brewis, Choudhary, & Wutich, 2019b). Water insecurity influences daily decisions about infant care and food preparation (Collins et al., 2019; Ngure et al., 2014); however, despite evidence of reciprocal relationships between diarrhea, stunting, and other nutritional disorders (Rice, Sacco, Hyder, & Black, 2000), we have insufficient understanding of how household decision making and poverty mediate these relationships in urban areas.

Exposure thresholds at which water insecurity and related stressors affect the body merit additional research. What are the biological thresholds at which water insecurity and its interactions with other stressors take a toll on

the human body? What are the immediate and long-term impacts of the different biological and social mechanisms by which water insecurity interacts with urban poverty to threaten health? For example, we know that water fetching by the urban poor entails navigating complex environments, carrying water over the head over long distances by mainly women and girls, and emerging evidence has uncovered injuries associated with water carriage (Geere, Bartram, et al., 2018; Geere, Cortobius, et al., 2018). However, at what threshold do these injuries have physiological and psychological impact on women and girls? And how are these injuries shaped by volume and weight of water routinely carried water carried by women and girls and what role does context play? Are there adaptive capacities within some urban environments as opposed to others? More work is also needed to understand what levels and urgency of interventions would effectively mitigate both short-term and long-term effects.

Finally, more studies are needed to understand how we can improve intervention efficacy by simultaneously addressing urban poverty, water insecurity, and other risk factors. Amid evidence that poverty and other risk factors influence the impact of water insecurity on health, more research should focus on strategies for intervention and implementation that simultaneously address multiple risk factors. Water supply interventions may not immediately address underlying psychosocial issues (Stevenson et al., 2012), suggesting that it is possible for other stressors to undermine the efficacy of water-health interventions. Evidence from Ethiopia shows that although water insecurity and psychosocial disorders are intricately linked, improvements in water supply may not immediately lead to improvements in psychosocial health (Stevenson et al., 2012). Where water insecurity co-occurs with poverty and psychosocial disorders, we need a better understanding of the right entry and integration points for improved intervention efficacy. Moreover, because the impacts of water insecurity are socio-economically differentiated and gendered (Adams, 2018a; Caruso, Sevilimedu, Fung, Patkar, & Baker, 2015), we must improve the design of interventions for more targeted outcomes.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

E.A.A. and J.S. conceptualized the article, conducted the literature review, and wrote the first draft. Y.A. contributed to the literature review and health outcomes section, and edited the article. All authors read, edited, and approved the final draft.

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