



Invisible struggles: WASH insecurity and implications of extreme weather among urban homeless in high-income countries - A systematic scoping review

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ABSTRACT

This paper aims to provide a deeper understanding of the water-, sanitation- and hygiene (WASH)-related insecurities that people experiencing homelessness in urban areas of high-income countries (HIC) are facing, and how these insecurities are further complicated during extreme weather events. While limited recent research has looked into WASH among people experiencing homelessness in HICs, and while some work has considering the implications of climate change on WASH and health, the nexus of WASH, extreme weather events and homelessness in HICs have not been studied thus far. We conducted the first systematic scoping review of peer-reviewed literature on this nexus, which is understudied and marked by complexity, involving a range of systems and forms of impact. A total of 50 publications were included in our analysis.

We found that public facilities like drinking water fountains, toilets, handwashing facilities, and showers are scarce, frequently unavailable, often pose safety and cleanliness issues, and access to non-public facilities may be cost-prohibitive for homeless populations. Consequently, people experiencing homelessness, including those sleeping rough, in encampments, or shelters, are often forced to limit drinking water consumption, forego healthy hygiene behaviours, and resort to open urination and defecation, all of which carry health risks. Extreme weather events, like heatwaves, extreme cold, heavy rain and flooding exacerbate challenges for people experiencing homelessness, further complicating their access to WASH, and reducing the ability of service providers to deliver extra relief, creating a dual WASH and health burden.

Our review highlights that the Human Right to Water and Sanitation is not met for people experiencing homelessness in urban areas of high-income countries, with women emerging as one of the most vulnerable subgroups. It reveals that the impact of certain WASH issues (e.g. drinking water) on homeless populations are better understood than others (e.g. waste), and, similarly, the effects of certain extreme weather events (e.g. heatwaves) on the health and WASH conditions of people experiencing homelessness are better understood than others (e.g. flooding). Data gaps and the lack of information on limited WASH access and health circumstances of people experiencing homelessness, further minimize their representation and consequently impose obstacles to improve their situation.

Based on our analysis, we established a framework which operationalizes the nexus of WASH, extreme weather events and homelessness. This framework improves our understanding of the underlying complexities at the intersection of these three issues and provides a foundation for enhanced preparedness and health-oriented planning.

1. Introduction

1.1. Homelessness. Definitions, drivers, and implications for ill-health and disease exposure

Homelessness is as diverse as the people and sub-populations experiencing it, and manifested, defined, and managed differently across cultures and world regions (Moffa et al., 2019). It covers a wide spectrum of inadequate accommodation and living circumstances that vary

in time (DeVuono-Powell, 2013). These range from sleeping rough or in the open to various forms of precarious and inadequate shelter arrangements (Every et al., 2021; Kidd et al., 2021) or other places not intended for human habitation (Ramin and Svoboda, 2009). While some are visible, in tents or sleeping bags on sidewalks, many people experiencing homelessness exist outside of public view, along rivers and other waterways, in canyons, and elsewhere in nature (Flanigan and Welsh, 2020). Homelessness is not static, with people affected often being highly mobile, moving between localities, e.g. shelters, friends'

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houses, and vacant buildings (Debska and Mosowska, 2021).

According to the United Nations, homelessness describes “persons living in streets or without shelter that would fall within the scope of living quarters; persons with no place of usual residence who move frequently between various types of accommodation (including dwellings, shelters or other living quarters); persons who usually reside in long-term (also called “transitional”) shelters or similar arrangements for the homeless” UNDESA, 2017). Winkleby (1990) classifies persons living in trailers, rooms, apartments, or houses as having permanent shelter, whereas those living on the streets, in tents, vehicles, or emergency shelters are classified as having no shelter. Nickasch and Marnocha (2009) define an individual experiencing homelessness as someone who sleeps at a public or private place not designed for regular sleeping accommodation for human beings, who lacks a fixed, regular, and adequate night time residence or has a primary night time residency that is a supervised publicly or privately operated shelter or institution that provides a temporary residence. These different types of homelessness have been classified into three different categories by English et al. (2022), with primary homelessness describing the lack of conventional housing and rough sleeping or sleeping in improvised dwellings; secondary homelessness describing those people frequently moving from one temporary shelter to another such as emergency accommodation, refuges or couch surfing; and people experiencing tertiary homelessness living in accommodations not meeting minimum community standards such as boarding housing or caravan parks.

DeMeyers et al. (2017) further specify shelter as temporarily in and out of low-income housing, in a homeless shelter, or in a drug rehabilitation center. Encampments refer to built or modified infrastructures with people residing there being part of a larger social network of campers (DeVuono-Powell, 2013; DeMeyers et al., 2017; Donovan et al., 2008; Palta et al., 2016). Different types encampments, usually at the edge of city limits, under bridges, in parks, by a freeway, near railway tracks, or a waterway, exist, that provide permanent, semi-permanent or temporary structures and well, semi-well or non-organized social network (DeVuono-Powell, 2013). Those sleeping rough, or with no roof live on the streets, and sleep in parks, underneath bridges, or abandoned buildings, but do not belong to a larger, social encampment system (DeMeyers et al., 2017).

For this scoping review, homelessness was categorized into three different types, including people sleeping rough, in encampments and in shelters (DeVuono-Powell, 2013; DeMeyers et al., 2017; Palta et al., 2016) (Table 1).

Baldwin (1998) portray different patterns of homelessness in terms of time, distinguishing short-term homeless, who are usually domiciled but become homeless for short periods of time; episodically homeless, who alternate between being domiciled or undomiciled; and chronically homeless, who regularly live on the street or in a shelter.

Homelessness is a complex, wicked, multi-faceted epidemic with various possible, diverse and unpredictable root causes and drivers. Triggers contributing to homelessness include personal (relationship

breakdown, family conflict, domestic and family violence, the loss of a partner), economic (unemployment, a shortage of affordable housing, eviction) and health factors (addiction to alcohol, drugs, gambling, mental or chronic illness, physical disability), which make the triggers and problem overall more complex than it already is (Cusack et al., 2013; Every et al., 2021; Flanigan and Welsh, 2020; Kyper et al., 2022; Portillo et al., 2022). Homelessness is associated with poverty, gender and sexual minorities, racial minorities, and a history of imprisonment (Moffa et al., 2019), and (health) risk factors differ with subgroups of people experiencing homelessness (Winkleby, 1990).

Under the definition of the United Nations, 100 million people worldwide are experiencing homelessness and 1.6 billion people lack adequate housing globally (Gibson, 2019). Numbers of people experiencing homelessness in high-income countries are substantial. For example, there were 582,000 people experiencing homelessness in the United States in 2022 (United States Department of Housing and Urban Development Office of Community Planning and Development, 2022); 235,000 in Canada in 2016 (Gaetz et al., 2016); 700,000 in Europe in 2020 (European Parliament, 2020); and 122,500 in Australia in 2021 (Australian Census of Population and Housing, 2021). Numbers are likely to be more extensive than these estimates, as surveys or shelter counts can miss intermittent or short-term homelessness and those who deny they are experiencing homelessness (Link et al., 1994; Moffa et al., 2019). While the number of people experiencing homelessness is increasing globally, investments in health-promoting services and infrastructure and anti-poverty programmes have been decreasing (Capone et al., 2020; Cutler and Miller, 2005; Nickasch and Marnocha, 2009) and low-income housing construction has been declining (DeVuono-Powell, 2013; Flanigan and Welsh, 2020). As such, according to Allaria et al. (2021), homelessness presents an extreme form of growing health inequality.

1.2. Health, disease, and implications of extreme weather events for people experiencing homelessness

Homelessness is associated with poor health outcomes and high mortality among individuals experiencing it due to the lack of access to proper medical care, delays in care-seeking, non-adherence to therapy and other vital resources, poverty, substance abuse, mental health issues, cognitive impairment, violence and trauma, and a high prevalence of health issues (Cusack et al., 2013; Kushel, 2018; Nickasch and Marnocha, 2009; Ramin and Svoboda 2009; Romaszko et al., 2017; Verbyla et al., 2021; Wandel et al., 2010; Winkleby, 1990). Cancer, heart disease, and cerebrovascular disease are major causes of death in people experiencing homelessness, and conditions such as obstructive lung disease, asthma, hypertension, high cholesterol and diabetes are often poorly controlled among this population group, lowering their immune response and making them more susceptible to opportunistic infections and infectious diseases overall (Ramin and Svoboda 2009), including bacterial, fungal and skin infections (Badiaga et al., 2008; Flanigan and Welsh, 2020; Portillo et al., 2022; Verbyla et al., 2021). Abdominal pain, gastroenteritis, nausea, vomiting, viral infections, respiratory tract infections and urinary tract infections are some of the most frequent reasons for emergency department use by homeless individuals (Moore et al., 2007; Portillo et al., 2022). Risk factors for infectious gastrointestinal and respiratory diseases – including COVID-19 (Capone et al., 2020) - include the conditions of crowding in shelters and camps, lack of, or unsafe, provision of drinking water, sanitation, and hygiene services, including hand-washing and excreta disposal (Ares et al., 2017; Bartram and Cairncross, 2010; Cairncross et al., 2010; Freeman et al., 2017; Leibler et al., 2016). Similarly, living conditions of urban homelessness and extreme poverty may result in contact with urban wildlife, rodents and insects, increasing exposure to vector-borne and zoonotic pathogens (Leibler et al., 2016). For other conditions, a major risk factor is direct exposure not only to (unhealthy) living environments, but also extended time spent outdoors, and exposure to extreme weather events

Table 1
Categorization of homelessness used in this scoping review, including people sleeping rough, in encampments and in shelters (DeVuono-Powell, 2013; DeMeyers et al., 2017; Palta et al., 2016).

Type of homelessness	Definition
Sleeping rough	With “no roof”, living on the streets, and sleeping in parks, underneath bridges, or abandoned buildings, not belonging to a larger, social system.
In encampment	Built or modified infrastructures, providing permanent, semi-permanent or temporary structures at the edge of city limits, under bridges, in parks, by a freeway, near railway tracks, or waterways with people residing there being part of a larger social network of campers.
Sheltered	Temporarily in and out of low-income housing, in a homeless shelter, or in a drug rehabilitation center.

such as heat, cold, heavy rains, flood etc.

According to Klein and Riemer (2011) and Gibson (2019), people experiencing homelessness have a particular vulnerability to environmental hazards. Baseline poor health is also a key risk factor for adverse health outcomes after disasters and extreme weather events (Ramin and Svoboda, 2009). According to Anderson et al. (2021), there are differences in terms of health status between different types of people experiencing homelessness, e.g. unsheltered people experiencing homelessness have poorer physical and mental health outcomes as compared to sheltered people experiencing homelessness, and this can be attributed to exposure to environmental conditions.

It is also estimated that 4 billion people are vulnerable to the effects of climate change and half a million more are at extreme risk. Related implications on disease exposure, health and well-being are not evenly distributed, and hit the poorest in a society the worst, as they are least-equipped to adapt and cope (Wandel et al., 2010). Exposure to extreme weather is a significant health issue for people experiencing homelessness due to the limited to no protection from the biophysical environment, the high prevalence of mental and physical health problems, limited resources to take adaptive measures and disengagement from health services, and their underrepresentation in disaster planning (Anderson et al., 2021; Cusack et al., 2013; Ramin and Svoboda 2009; Romaszko et al., 2017; Wandel et al., 2010). Exposure to harsh environments may exacerbate the poor health of people experiencing homelessness, particularly when unsheltered - and health-related vulnerabilities (e.g. mental health condition) may increase the likelihood of a person choosing to remain outdoors in harsh environments (Anderson et al., 2021). In particular, people experiencing homelessness are vulnerable to heat and cold exposure (Ramin and Svoboda 2009).

Global warming has resulted in an increase in the frequency and duration of *heatwaves* (English et al., 2022) - extended periods of uncommonly high atmosphere-related heat stress - which have been defined as “periods of abnormally and uncomfortably hot and usually humid weather” (Nicolay et al., 2016). The severity of the symptoms depend on pre-existing medical conditions and include nausea, emesis, fatigue, weakness, headache, muscle cramps, and dizziness and can progress to heat stroke causing tachycardia, hypernatraemia, renal failure, cardiovascular complications, difficulty breathing, altered mentation, hallucinations, seizures, coma, and death (Cusack et al., 2013; English et al., 2022; Every et al., 2021; Nicolay et al., 2016). In the United States, up to 91% of homeless populations live in urban or suburban areas, where they are at increased risk from heatwaves due to the heat island effect which occurs because built structures absorb heat that is then re-radiated thereby causing urban areas to be 5–11 °C warmer than surrounding rural regions (Cusack et al., 2013; Ramin and Svoboda 2009). In summer this creates and increases the risk of heat stress for those who are unable to move into cooler conditions (Cusack et al., 2013). Public access – or lack thereof - to water is a major risk factor during extreme heat, as is food security, with the homeless being particularly vulnerable (Kidd et al., 2021).

In large parts of the Northern Hemisphere, (*extreme*) cold weather conditions prevail during the winter months. Extreme cold refers to near freezing temperatures (Cusack et al., 2013). People experiencing homelessness, who often spend prolonged periods of time outside during the days and nights, are at increased risk of cold weather-related health conditions, injury and death. Rain, wet conditions, inadequate clothing, pre-existing health issues, mental health issues and substance use disorders increase this risk. One consequence is hypothermia, characterized by abnormally low body temperatures (<35°C), cardiovascular, and central nervous system dysfunction, and potentially fatal outcomes. Hypothermia risk increases with declining temperature; however, most cases occur during periods of low and moderate cold stress (Zhang et al., 2019). A study conducted in Olsztyn, Poland, associating mortality among people experiencing homelessness and meteorological conditions, found most deaths occurred in the conditions of cold stress (of different intensity). Deaths caused by hypothermia were thirteen-fold

more frequently recorded among the homeless than for the general population (Romaszko et al., 2017). Similarly, Kidd et al. (2021a,b) in their review of climate change implications on people experiencing homelessness, found both moderately cold and extremely cold temperatures present significant risks, cold-related morbidity and mortality to this vulnerable population.

Floods, heavy rain and storms also disproportionately impact vulnerable populations and people experiencing homelessness in particular (Cusack et al., 2013), with adverse health implications including drownings, infectious disease outbreaks, and an increased incidence of anxiety and depression (Ramin and Svoboda 2009; Zhang et al., 2018).

1.3. The importance of WASH security for people experiencing homelessness

What makes extreme weather events particularly challenging for people experiencing homelessness is their often widespread inability to meet their basic needs (Pendrey et al., 2014), the barriers to accessing drinking water, sanitation, and hygiene (WASH) services, and associated health risks, all of which have been largely understudied (Ares et al., 2017; Capone et al., 2020; Moffa et al., 2019; Verbyla et al., 2021). Flush toilets, sewers, and septic tanks, as well as a personal hygiene and clean, hygienic living environments, provide a physical barrier between people and their excreta and are therefore important to prevent infection by fecal-oral pathogens via well-understood pathways of transmission (Bradley, 1974; Capone et al., 2020). WASH access is closely tied to housing, and that leaves provision, financing, regulation, and maintenance of WASH to the responsibility of the property owners (Ramsden, 2020), and those who lack stable housing, including people experiencing homelessness (de Gómez, 2010) in urban areas, are often excluded (Brown et al., 2023; Capone et al., 2020; DeMeyers et al., 2017). Open defecation and overuse of limited available WASH facilities threaten public health, as demonstrated by recent infectious disease outbreaks associated with poor sanitation among people experiencing homelessness (Frye et al., 2019), including outbreaks of Hepatitis A in California (Kushel, 2018), high risk of enteric infections in Atlanta, Georgia (Capone et al., 2018), leptospirosis in Lisbon, Portugal and Tokyo, Japan, resulting from drinking unsafe water from puddles, eating food from trash bins, limited access to sanitation, proximity to rodents, animal faeces and urine and overall poor hygiene (Kang et al., 2015; Moreira Marques et al., 2020), *Mycobacterium tuberculosis* infections, methicillin-resistant *Staphylococcus aureus* (MRSA) and diarrheal diseases, asthma or asthma-like symptoms, skin and eye diseases and louse-related conditions (Moffa et al., 2019).

Sustainable Development Goal (SDG) 6, which calls for universal access to water, sanitation, and hygiene services includes environmental health in non-household settings, including involuntarily displaced person settings such as homeless shelters (Moffa et al., 2019; United Nations, 2014), underlining the societal and political relevance of WASH (in)security among people experiencing homelessness.

1.4. Bringing three concepts together

Homeless individuals have higher rates of pre-existing health issues, greater exposure and poorer protection from extreme weather events such as heatwaves, storms, heavy rains, floods and extreme cold conditions, and are more likely to occupy high-risk urban areas (Ramin and Svoboda, 2009) that fail to provide safe drinking water, sanitation and hygiene. To prevent exposure to infectious diseases, the provision of safe WASH is crucial, during “normal” times, and even more crucial during periods of extreme weather events. For millions of homeless people, homeless station missions, accommodation services and public restrooms are critical and sometimes the only option for accessing WASH services. Such services have become less common over the past decades (Molotch and Noren, 2010), leaving homeless communities without year-round access, and exposed to water-related health risks (Badiaga

et al., 2008; Fazel et al., 2014). What is challenging under normal circumstances already, gets further complicated during extreme weather events: during heatwaves, more water for hydration and cooling may be needed; during flooding, public restrooms and services may be inaccessible; during extreme colds, water supply may be dysfunctional (Howard et al., 2016). Despite the high societal relevance of *leaving no one behind* accessing WASH as per SDG 6, and despite the Human Right to Water and Sanitation, the needs of homeless communities have not only not yet been fully met; WASH inequalities and resulting disease burden remain hidden in official statistics and understudied. And despite increasing frequency, intensity and unpredictability of extreme weather events (IPCC, 2022), and evidence that extreme weather events significantly shape the daily experiences of people at risk of homelessness (Every and Richardson, 2017; Walters and Gaillard, 2014), implications on WASH infrastructure, and consequences on their health (Ramin and Svoboda, 2009) have not been comprehensively studied either. The detailed links between WASH insecurity, extreme weather events and homelessness in high-income countries (HIC) have to date not been investigated.

We aim to fill the combined knowledge gap in understanding the challenges that homeless communities in urban areas in HICs are facing with regard to WASH insecurity overall, and specifically with regard to accessibility and usability of WASH during extreme weather events, building on a previous systematic scoping review by Moffa et al. (2019), aimed at exploring evidence (gaps) in hygiene behaviors, environmental health conditions and health outcomes in homeless shelters, a review by Brown et al. (2023), investigating the effects of racism, social exclusion, and discrimination on achieving universal safe water and sanitation in HICs, and research related to climate resilient WASH (Anthonj et al., 2020a; Fleming et al., 2019; Howard et al., 2016).

2. Methods

To identify and understand evidence on the nexus of WASH, extreme weather events and homelessness, a research topic which i) is complex in terms of types of impact and systems involved, ii) understudied and iii) combines different knowledge gaps, we chose a systematic scoping review approach. We followed the five-stage scoping review framework defined by Arksey and O'Malley (2005) and advanced by Levac et al. (2010), identifying the research question and relevant results, selecting studies, extracting information from included studies, and reporting results. Questions that we aimed to address with this review include:

1. Which WASH- and health-related challenges are homeless people in urban areas in high-income countries facing?
2. In what way do extreme weather events complicate WASH access and exposure to health risks?
3. Which methods/tools have been used to capture homeless peoples' WASH & health challenges and interventions?
4. How can climate-resilient and inclusive WASH for homeless communities in cities be improved?

2.1. Search strategy

In an iterative process involving three of the authors, a search strategy was developed to identify the peer-reviewed literature relevant to these research questions, and based on it, a review was executed between January and July 2023. After being piloted with Scopus, the search strategy was modified for Web of Science and MEDLINE (via PubMed), all of which were searched for peer-reviewed literature.

We conducted this scoping review literature search in adherence with the preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2016). We divided our search terms into three blocks, namely: water, sanitation and hygiene (WASH) (Block 1); people experiencing homelessness (Block 2); and climate, weather

and climate resilience (Block 3). Blocks were combined using boolean operator AND while search terms within the blocks were combined using boolean operator OR. Medical Subject Headings (MeSH) were exclusively included in searches conducted in MEDLINE (via PubMed). Definitions of terms are available in Supplementary file 1. The detailed search strategies applied for each database are available in Supplementary file 2.

2.2. Selection of studies

Titles and abstracts of each publication were screened and checked against the inclusion and exclusion criteria for a full-text review (Table 2). Only studies meeting the criteria, and on the thematic, combining two or more of the different search blocks, were included. There were no publication date restrictions. In addition, reference lists were scanned for additional relevant papers which, if eligible, were included as well. The typology for homelessness followed DeMeyers et al. (2017), and distinguished people experiencing homelessness i) sleeping rough, ii) in encampment, iii) in shelters. With regards to location, only studies conducted in urban and peri-urban areas or informal settlements in HICs (according to the latest classification of World Bank Classification) were considered eligible. Any literature meeting one or more of the criteria shown in Table 2 was excluded.

2.3. Data extraction and analysis

Information that we extracted from each included study included: (i) study characteristics (e.g., year and country of publication, setting details, study population, (ii) methodological approach (e.g. aim, methods, limitations), (iii) a summary of those findings relevant to answer our research questions on climate-resilient WASH and health (risks) among people experiencing homelessness, and (iv) recommendations resulting from the different studies. After extraction, data were tabulated to identify trends across studies and contextualize and synthesize results (Tables 3 and 4). Based on the results of this review, the complex links were operationalized, and displayed in the Climate-Resilient WASH for Homeless Framework (Fig. 2).

3. Results

3.1. Search results and study characteristics

The screening process used for this scoping review is detailed in Fig. 1, and resulted in 50 studies included in the final analysis.

Table 2

Inclusion and exclusion criteria for the scoping review of literature on climate-resilient WASH infrastructure among people experiencing homelessness in cities.

Criteria	Inclusion	Exclusion
Location	Study was conducted in urban or peri-urban or urban informal settlement area	Study was conducted in rural area
	Study was conducted in high-income country as per World Bank Classification ^a	Study was conducted in low- or middle-income country
Population	Related to people experiencing homelessness i) sleeping rough, ii) in encampments, iii) in shelters	Related to refugee shelter or sudden-onset homelessness due to disaster
Language	Published in English	Not in English
Thematic	Combining two, or all of the concepts water, sanitation and hygiene (WASH); climate, weather and climate resilience; people experiencing homelessness.	Not on the thematic

^a How does the World Bank classify countries? – World Bank Data Help Desk.

Table 3

Articles identified in the scoping search on climate-resilient WASH infrastructure among people experiencing homelessness in cities meeting two or more criteria.

Author (year)	Study objective	Location	Method	study population			
				with no roof	encampment	shelter	not specified
Allaria et al. (2021)	Describe protective measures, assess skills and resources during COVID-19 among PEH	Marseille, France	Mixed methods: survey, in-depth interviews	x	x	x	
Amato et al. (2022)	Assess the impact of public restroom interventions on reports of exposed faeces	San Francisco, California, USA	Quantitative: impact evaluation, time-series analysis, spatial analysis	x			
Anderson et al. (2021)	Examine associations between biophysical and social environments and health	Nashville, Tennessee, USA	Quantitative: survey	x			
Ares et al. (2017)	Document availability of public toilets	Skid Row, Los Angeles, California, USA	Quantitative: toilet inspections				x
Baldwin (1998)	Explore adaptation of mentally ill women to homelessness	Skid Row, Los Angeles, California, USA	Qualitative: in-depth interviews, observation, longitudinal study	x		x	
Capone et al. (2018)	Survey spatial distribution and enteric pathogen profile of human faeces	Atlanta, Georgia, USA	Quantitative: stool sampling	x		x	
Capone et al. (2020)	Estimate the population lacking water and sanitation	USA	Quantitative: secondary data analysis				x
Chen et al. (2014)	Understand and address care needs of PEH	San Francisco, California, USA	Quantitative: survey	x	x	x	
Cusack et al. (2013)	Identify extreme weather-related health needs of PEH and responses by service providers	Adelaide, Australia	Mixed methods: in-depth interviews, literature review	x		x	
Debska and Mosowska (2021)	Investigate links between homelessness and gender	A metropolitan area, Poland	Qualitative: in-depth interviews	x		x	
de Gómez (2010)	Understand how urban PEH adapt to environmental change	Waterloo, Canada	Qualitative: participatory action research				
DeMeyers et al. (2017)	Examine governance successes and failures of water infrastructure	Phoenix, Arizona, USA	Mixed methods: survey, in-depth interviews, observation, secondary data analysis, focal follows	x	x	x	
DeVuono-Powell (2013)	Develop recommendations to reduce pollution caused by homeless encampments	Contra Costa county, California, USA	Qualitative: in-depth interviews, observation		x		
Donovan et al. (2008)	Evaluate risk of pathogen-related disease in waterbodies among different users, incl. PEH	New Jersey, Lower Passaic River, USA	Quantitative: water sampling		x		
English et al. (2022)	Report heat illness requiring emergency care in PEH	Sydney, Australia	Quantitative: secondary data analysis				x
Every et al. (2021)	Evaluate experiences of heat stress and dehydration of people sleeping rough	Adelaide, Australia	Quantitative: survey	x			
Feinstein and Daiess (2019)	Assess access to toilets, hot and cold running water	California, USA	Quantitative: secondary data analysis				x
Felner et al. (2020)	Examine experiences and needs of homeless youths affected by a Hepatitis A outbreak	San Diego, California, USA	Mixed methods: in-depth interviews, photography, videography, interactive participatory sessions, historical analysis				x
Flanigan and Welsh (2020)	Explore health and human service needs of people living near waterways	San Diego River, USA	Mixed methods: in-depth interviews, literature review		x		
Frye et al. (2019)	Understand open defecation among PEH	USA	NA				x
Gibson (2019)	Understand links between climate change and homelessness	NA	NA				x
Ho et al. (2007)	Describe impact of living environments on health and access to care for people with disabilities	District of Columbia, USA	Qualitative: focus group discussion			x	
Kidd et al. (2021)	Understand health and social implications of global climate change on homelessness	global	Quantitative: literature review	x		x	
Kidd et al. (2021)	Understand climate change and homelessness nexus	global	NA				x
Klein and Riemer (2011)	Understand environmental experiences of PEH	Waterloo, Canada	Mixed methods: survey, in-depth interviews, participatory action research	x	x	x	
Kyper et al. (2022)	Understand the use of emergency department services by PEH	USA	Quantitative: secondary data analysis				x
Leibler et al. (2016)	Identify risk factors for vector-borne and zoonotic infections among PEH	USA, Europe	Quantitative: literature review				x

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Table 3 (continued)

Author (year)	Study objective	Location	Method	study population			
				with no roof	encampment	shelter	not specified
Leibler et al. (2017)	Identify self-care practices and risk factors for reduced hygiene among PEH	Boston, Massachusetts, USA	Quantitative: survey	x	x	x	
Lupien et al. (2018)	Examine water and toilet access among unsheltered PEH, recommend minimum standards	California, USA	Mixed methods: in-depth interviews, document review, policy review	x			
Marcus et al. (2020)	Describe response to announcement of COVID-19 lockdown	Caledonian Stadium, City of Tshwane, South Africa	Qualitative: in-depth interviews		x		
Moffa et al. (2019)	Explore hygiene behaviors and environmental health conditions in homeless shelters	Homeless shelters, global	Quantitative: literature review			x	
Moreira Marques et al. (2020)	Understand case of Weil's disease in a young homeless man	Lisbon, Portugal	Mixed methods: in-depth interviews, observation, blood tests, urine tests, medical examinations	x			
Nickasch and Marnocha (2009)	Explore healthcare experiences of homeless individuals	Northeastern Wisconsin, USA	Mixed methods: in-depth interviews, literature review, grounded theory	x		x	
Nicolay et al. (2016)	Evaluate response to natural disaster, health status, assess reliability of drinking water	Tampa Bay, Florida, USA	Quantitative: survey				x
Palta et al. (2016)	Examine access to ecosystem services by PEH	Phoenix, Arizona, USA	Mixed methods: in-depth interviews, observation, secondary data analysis, water sampling, spatial study				x
Pendrey et al. (2014)	Address impacts of extreme weather on health and well-being of PEH	Inner City of Adelaide, Australia	Qualitative: in-depth interviews				x
Pinongcos et al. (2022)	Identify sources and dynamics of human-associated fecal contamination in river during storm	Southern California, USA	Quantitative: temporal analysis		x		
Portillo et al. (2022)	Examine WASH access among unhoused communities, describe coping and access to WASH	Skid Row, Los Angeles, California, USA	Quantitative: survey				x
Ramin and Svoboda (2009)	Review impacts of climate change on PEH	USA	Quantitative: literature review				x
Romaszko et al. (2017)	Verify risk of increased mortality related to meteorological conditions among PEH	Olsztyn, Poland	Quantitative: secondary data analysis				x
Rosengard et al. (2001)	Investigate health-related practices in homeless women	San Francisco, California, USA	Quantitative: survey			x	
Rosenthal et al. (2022)	Describe indoor environmental health challenges for children experiencing homelessness	London, UK	Mixed methods: survey, collaborative meetings			x	
Sanchez (2011)	Investigate heat-related coping strategies of PEH	Phoenix, Arizona, USA	Qualitative: in-depth interviews				x
Steele et al. (2017)	Identify upstream sources of human fecal contamination during wet weather	San Diego River watershed, USA	Quantitative: water sampling, precipitation measurements, Enterococcus cultivation, filtration and extraction of bacteria and viruses				x
Verbyla et al. (2021)	Assess water quality around homeless encampments and WASH-related perceptions	San Diego, California, USA	Mixed methods: In-depth interviews, water sampling		x		
Wandel et al. (2010)	Assess present and future vulnerability of PEH to climate change	Cambridge & Kitchener, Waterloo, USA	Mixed methods: in-depth interviews, secondary data analysis		x	x	
Wescoat et al. (2006)	Understand low-income water programs serving small communities	Colorado, USA	Quantitative: secondary data analysis, document review				x
Winkleby (1990)	Examine risk factors for ill health among PEH	San Jose, California, USA	Quantitative: survey	x		x	
Zhang et al. (2018)	Determine rate of emergency department visits for cold-related injuries among PEH	Toronto, Canada	Quantitative: survey	x		x	
Zhang et al. (2019)	Examine association between meteorological conditions and hypothermia risk among PEH	Toronto, Canada	Quantitative: secondary data analysis, document review				x

Legend: PEH is an abbreviation for people experiencing homelessness.

Table 4
Content covered by literature included in review, related to WASH, weather, climate, health.

Author (year)	WASH							weather and climate					health	
	drinking water	sanitation	open defecation	hygiene	menstrual hygiene	waste & wastewater	natural water resources	heat	flood	cold	storm & rain	climate change	health	healthcare
Allaria et al. (2021)	x												x	
Amato et al. (2022)		x	x											
Anderson et al. (2021)										x			x	
Ares et al. (2017)		x			x									
Baldwin (1998)				x	x								x	
Capone et al. (2018)		x	x											
Capone et al. (2020)	x	x												
Chen et al. (2014)				x									x	
Cusack et al. (2013)	x	x		x				x		x			x	
Debska and Mosowska (2021)				x										
de Gómez (2010)	x							x		x	x			
DeMeyers et al. (2017)	x						x	x						
DeVuono-Powell (2013)						x	x	x	x		x			
Donovan et al. (2008)	x					x					x		x	
English et al. (2022)	x							x					x	
Every et al. (2021)	x							x					x	
Feinstein and Daless (2019)	x	x												
Felner et al. (2020)		x		x									x	
Flanigan and Welsh (2020)	x	x	x	x			x	x	x				x	x
Frye et al. (2019)		x	x										x	
Gibson (2019)												x		
Ho et al. (2007)		x											x	x
Kidd et al. (2021)	x							x	x	x		x	x	
Kidd et al. (2021)												x	x	
Klein and Riemer (2011)						x								
Kyper et al. (2022)				x							x		x	x
Leibler et al. (2016)													x	
Leibler et al. (2017)				x									x	
Lupien et al. (2018)	x	x		x										
Marcus et al. (2020)		x		x		x				x	x		x	
Moffa et al. (2019)	x	x		x									x	
Moreira Marques et al. (2020)	x					x							x	
Nickasch and Marnocha (2009)				x									x	x
Nicolay et al. (2016)	x							x			x			
Palta et al. (2016)	x			x			x	x			x		x	
Pendrey et al. (2014)	x							x	x				x	
Pinongcos et al. (2022)			x								x			
Portillo et al. (2022)	x	x	x	x	x								x	
Ramin and Svoboda (2009)								x	x	x		x	x	
Romaszko et al. (2017)								x		x			x	
Rosengard et al. (2001)				x										
Rosenthal et al. (2022)		x		x		x				x			x	
Sanchez (2011)	x			x				x					x	
Steele et al. (2017)			x			x					x			
Verbyla et al. (2021)	x	x												
Wandel et al. (2010)	x							x	x	x	x		x	
Wescoat et al. (2006)	x	x		x				x						
Winkleby (1990)	x									x			x	
Zhang et al. (2018)										x			x	
Zhang et al. (2019)										x			x	

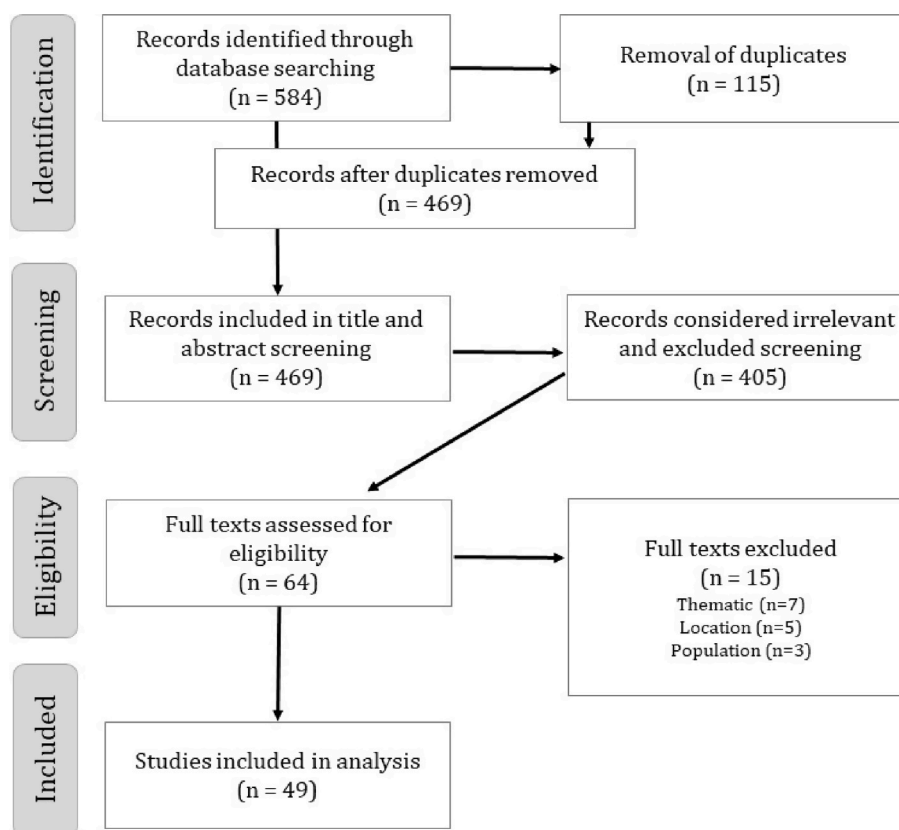


Fig. 1. PRISMA flowchart for the systematic literature review on climate-resilient WASH and health (risks) among people experiencing homelessness in cities.

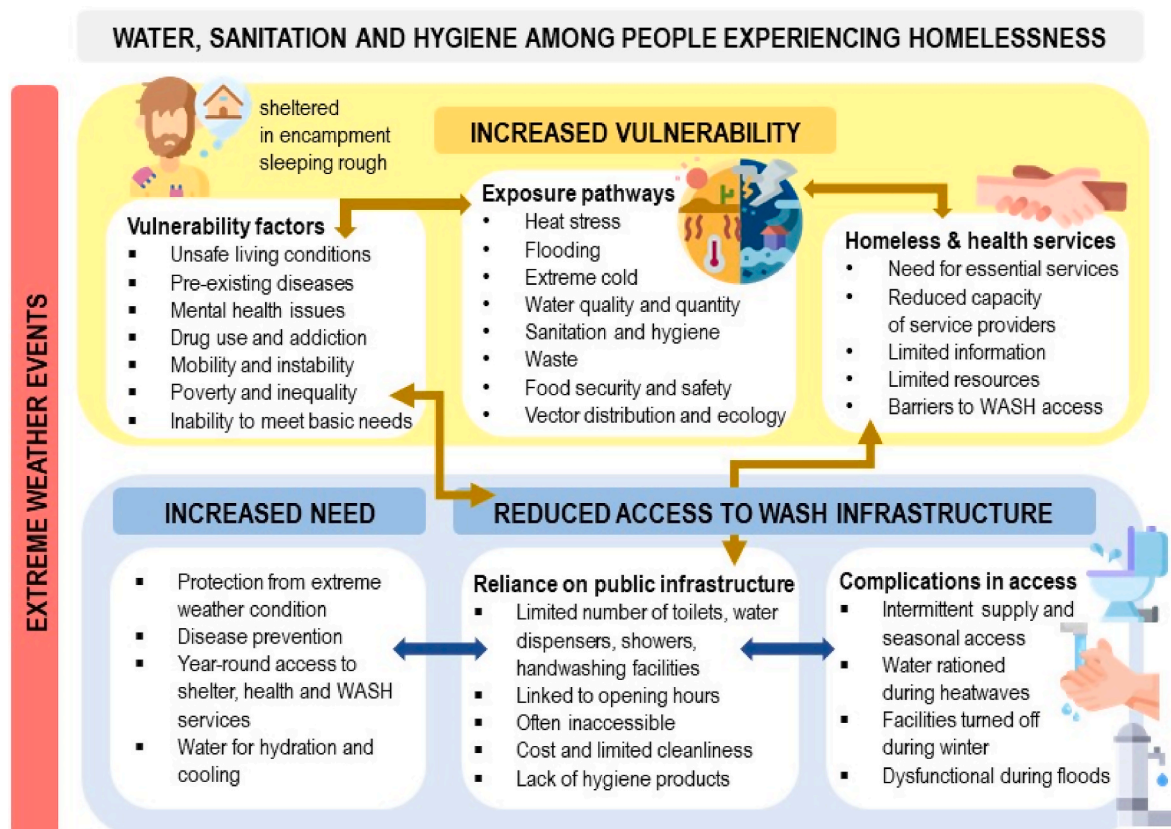


Fig. 2. Climate-Resilient WASH for People Experiencing Homelessness Framework (informed by the results of this review).

The studies included in this scoping review point to a growth in literature on climate-resilient WASH and health (risks) among people experiencing homelessness in cities in HICs over the past twenty years. Included studies reported information from North America (72%), Europe (10%), Australia (8%), and Africa (2%). While all included studies considered people experiencing homelessness, the study populations and type of homelessness varied. We distinguished people i) sleeping rough, ii) in shelters, and iii) in encampments (Table 3).

Climate-resilient WASH and health (risk) studies among people experiencing homelessness in cities in HICs were conducted in different contexts, ranging from health and disease exposure, incl. mental health and COVID-19; to WASH insecurity and Human Right to Water and Sanitation; climate change and extreme weather events related to health; environmental (in)justice and social inequality; water and poverty; and gender. Studies were also conducted by researchers representing a wide range of disciplines.

3.2. Methodological approaches and limitations to studying climate-resilient WASH and health (risks) among people experiencing homelessness in cities

Included studies adopted quantitative, qualitative and mixed methods approaches (Table 3). Most studies used a semi-quantitative on-site questionnaire, and qualitative methods such as semi-structured in-depth interviews were frequently employed. Several studies relied on secondary data sources, or literature reviews. Few studies conducted spatial assessments, longitudinal, time-series or temporal analyses, impact evaluations or participatory action research, and only one study grounded theory.

Studies included in this review had pitfalls and various limitations, e. g., not providing information regarding the limitations of their research, small sample sizes, study design, limited data availability and different kinds of bias.

3.3. Overview mapping of climate-resilient WASH and health (risks) among people experiencing homelessness in cities

Topics covered in the literature in the context of climate-resilient WASH and health (risks) among people experiencing homelessness in cities in high-income countries were broad. Emerging themes centred mainly around i) WASH - drinking water, sanitation, open defecation, hygiene, menstrual hygiene and waste(water)-related topics, natural water resources; ii) weather and climate: heat, flooding, cold, storm and heavy rain and climate change; iii) health: health (risks) and healthcare. We categorized our results based on these emerging themes (Table 4).

In terms of WASH and homelessness, almost half of the included studies (46%) looked at drinking water (source, quality, safety), 36% of studies centred around hygiene (handwashing, hygiene behaviour), 6% on menstrual hygiene management, 34% of studies explored sanitation, 14% considered open defecation, and 14% of studies focused on waste and wastewater management. Natural water resources were addressed in 8% of the included studies. In terms of weather, climate and homelessness, 32% of studies investigated heatwaves, 26% extreme cold, 20% storm and rain, 12% flooding and 8% climate change in general. In terms of health (risk) and homelessness, 64% of studies reported on a health risk or disease, and 8% of studies reported on healthcare services provided or accessed (Table 3).

Only one third of the included papers reported in some detail on the links between climate-resilient WASH and health among people experiencing homelessness in urban areas in HICs (Cusack et al., 2013; Donovan et al., 2008; English et al., 2022; Every et al., 2021; Flanigan and Welsh, 2020; Kidd et al., 2021a,b; Marcus et al., 2020; Palta et al., 2016; Pendrey et al., 2014; Ramin and Svoboda, 2009; Romaszko et al., 2017; Rosenthal et al., 2022; Sanchez, 2011; Wandel et al., 2010; Winkleby, 1990), while all others only marginally touched upon the links (Table 3).

3.4. Drinking water, sanitation and hygiene conditions among people experiencing homelessness in cities in high-income countries

3.4.1. Drinking water

A study by Portillo et al. (2022) that explored WASH insecurity in Los Angeles, United States found 71% of unhoused individuals reported having at least basic access to improved drinking water (WHO and UNICEF, 2019) from sources within 30 min of their sleeping location in the morning, purchasing bottled water, free water from department stores, or refilling plastic bottles using public fountains in parks and libraries. Of the people interviewed, 10% reported limited access to drinking water sources in the morning and 13% reported varying distances. Illegally opening fire hydrants to meet their daily drinking water needs was common too. Accessing drinking water in evenings was more challenging, and limited by opening hours of supermarkets, dollar stores, and public facilities (parks and libraries). In evenings, 19% of the unhoused persons reported not having basic access to drinking water, and about half refilled or bought plastic bottles to store it for night use. Safety concerns were raised regarding purchasing water at night. The total daily water intake was about three bottled water (only 1.5 L) a day for about half of the respondents. A study by Feinstein and Daless (2019) on running water in California, United States, revealed that around 120,000 people experiencing homelessness were unlikely to have adequate access to hot and cold running water, and 17,000 stand-alone structures, including temporary shelters, lacked an indoor running water. Exploring unmet (health) needs of people experiencing homelessness and residing near waterways in San Diego, United States, Flanigan and Welsh (2020), when interviewing 56 individuals living in riverbeds or canyons, found concerns over access to water being communicated by one third of all interviewees. Their study revealed that for drinking, 48% of people experiencing homelessness interviewed purchase bottled water, and of the 62% that use drinking fountains and tap water, the vast majority accesses it from restaurants or from hose spigots at business establishments and private apartment complexes. DeMeyers et al. (2017), on the other hand, found people experiencing homelessness in shelters or drug rehabilitation centres in Phoenix, Arizona, facing little or no problems accessing running water and cooling as tap water sources provided are usually relatively dependable, and air-conditioning services rather reliable. Though tap water is provided, many people prefer to drink bottled water which often is offered in fixed quantities (e.g. two bottles per person per day). Shelters are not available 24/7, and people living in shelters do not usually stay in the shelters during the day. Thus, while spending the daytime hours out on the streets, other water sources need to be tapped. These are often public water fountains, bottled water from a store, for free from a business, or from donations. Ho et al. (2007) found water in shelters is sometimes cut off.

Encampments are often marginalized, as are their sources of water. Research from Arizona revealed that people experiencing homelessness in encampments therefore commonly use surface water, rainwater, canal water, and water that collects in retention zones, for cooling and for drinking, unless they have direct access to bottled water through vendors or volunteers, to private tap water through sprinklers or nearby businesses or to public fountains (DeMeyers et al., 2017). Living in (urban) riverine encampments, where water quality is often poor and unsafe for drinking, bathing or contact with human skin, often comes with specific health risks (Palta et al., 2016). According to Flanigan and Welsh (2020), people experiencing homelessness in San Diego at river-bank encampments were 2.8 times more likely to use untreated river water for non-potable purposes than non-river dwelling individuals.

Rough sleepers in Arizona rely mainly on water fountains, bottled water distributed through volunteers and water trucks, on businesses and gas stations allowing them to drink water and refill their bottles to access drinking water, and use public restrooms, surface water, sprinklers or spigots by houses to cool-off (DeMeyers et al., 2017).

3.4.2. Sanitation

People experiencing homelessness in the United States commonly face barriers to accessing sanitation facilities when and where they are needed (Capone et al., 2018; Portillo et al., 2022), relying on public toilets, homeless service institutions and shelters, privately owned business toilets (Amato et al., 2022), cafes, department stores or gas stations for their sanitation needs.

A study by Feinstein and Daies (2019) on lack of toilets and running water in California, revealed that around 120,000 people experiencing homelessness were also unlikely to have adequate access to a toilet, and 17,000 stand-alone structures, including temporary shelters, lacked an indoor flush toilet and access to shared facilities in the building. The majority (86%) of households with incomplete plumbing lacked either a toilet, hot and cold water, or both, and income and race were correlated with incomplete plumbing by census tract.

In shelters, sanitation access is often challenging (Flanigan and Welsh, 2020). Having to share with many other people toilets, many of which were unclean, poorly ventilated, broken or unusable, in overcrowded shelters, was perceived as problematic by people experiencing homelessness in London, UK (Rosenthal et al., 2022) and District of Columbia, United States (Ho et al., 2007). Besides, sanitation facilities are often not wheelchair accessible, resulting in people experiencing homelessness staying in shelters refraining from using the bathrooms (Flanigan and Welsh, 2020; Ho et al., 2007).

According to Flanigan and Welsh (2020), rather than interacting with government or nonprofit service providers, people experiencing homelessness rely mainly on private businesses to meet bathroom needs. According to their study in San Diego, United States, 69% rely on restaurants and gas stations for bathroom access, compared to the 7% that rely on homeless service providers. These are often unsanitary, with trash accumulating in corners, floors being dirty, and soap dispensers being empty (Felner et al., 2020). Besides, access to toilets in department stores or gas stations is restricted opening hours, distance, customer-only policies, discrimination against people experiencing homelessness by staff members and customers, and insufficient levels of cleanliness, maintenance, and monitoring (Frye et al., 2019; Lupien et al., 2018).

According to Portillo et al. (2022), in Los Angeles, United States, access to shared sanitation fluctuates throughout the day, with different types of sanitation being used based on the time of the day. While public toilets in parks, libraries, staffed Pit Stop program toilets, and non-profit hygiene centres were used during the day, accessing sanitation was reduced and particularly difficult at night, resulting in 19% of the unhoused individuals interviewed in their study coping by using buckets inside their tents or plastic bottles and 28% openly defecating and urinating in public spaces. Besides, the interviewees reported holding it at night and waiting until the morning to use a restroom.

Of all public toilets reported to be functional and available in Arizona, 16% were found to be unsanitary to the point of dysfunction, closed or locked during open hours, or inaccessible due to other factors such as private events (DeMeyers et al., 2017). The number of public toilets in the New York City subway system, focal point to many people experiencing homelessness, was once 1676, but decreased to only 129 at present. An audit of public toilets in Skid Row, Los Angeles, revealed that 1777 people experiencing homelessness relied on just 9 public restrooms during nighttime hours, falling 80 toilets short of the UN sanitation standards (Ares et al., 2017; Frye et al., 2019).

During daytime hours (6:00 a.m. to 9:00 p.m.), when shelters release many of their overnight occupants onto the street, the unsheltered population swells. During these hours, Skid Row is short of the United Nations sanitation standard by 164 public toilets. The audit revealed issues with regard to toilet functioning, with half of the few existing toilets were out of service, powered down overnight and inaccessible, not operating during supposedly opening hours, and lacking sinks. There were problems related to maintenance as well: Most of the toilets lacked soap, paper towels, toilet paper and seat covers, as well as menstrual

hygiene products. Maintenance of automated, portable and indoor provider toilets were infrequent, and their self-cleaning feature did not always work. Some toilets were unsafe for use due to the amount of fecal matter and debris. Even though public, toilets were hard to be found due to insufficient signage and besides, access differed based on race and class. Changing tables were scarce in public toilets. Privacy could hardly be guaranteed either, as many toilets lack stalls, doors or locks. Furthermore, safety was an issue, as toilets lacked attendants or monitoring, and entry or exit from automated public toilets was unsafe to use even when functioning due to people standing around or near the toilet. Finally, toilets were rarely accessible for wheelchair users (Ares et al., 2017).

The lack of public WASH resources, distance and inaccessibility, unhygienic conditions, negative experiences and perceptions about public toilets, feelings of being unwelcome at service centres, concerns about safety, and cognitive impairment, physical and mental illness—including addiction—and fear, mistrust, stigma or social phobia are all factors that contribute to open defecation. People experiencing homelessness are often forced to practice open defecation on streets and sidewalks (Capone et al., 2020; Frye et al., 2019), which according to Capone et al. (2018), is relatively common in the urban United States, despite global statistics that suggest universal access to sanitation (WHO and UNICEF, 2019). Sleeping rough, in particular, is a predictor of poor sanitation practices (Leibler et al., 2017). For rough sleepers, open defecation can be borne out of practical necessity as without permanent and safe storage for their belongings, they risk losing their possessions when they are unable to defecate nearby (Frye et al., 2019). A study conducted in Atlanta, Georgia identified and mapped open defecation sites and found that of the 39 open defecation sites containing 118 presumptive human stools, the majority (92%) were within 400 m of a shelter for people experiencing homelessness or a soup kitchen, suggesting that sanitary needs of persons experiencing homelessness are not met. Of the open defecation sites identified, the majority offered some privacy or shelter, and they were typically located underneath overpasses, by dumpsters, in narrow alleys and stairwells (Leibler et al., 2017).

Open defecation is also common among people experiencing homelessness residing near rivers and waterways, as there is usually little or no access to sanitation facilities (DeMeyers et al., 2017). According to Flanigan and Welsh (2020), people experiencing homelessness in San Diego at riverbank encampments were 1.9 times more likely to practice open defecation, compared with non-river dwelling individuals. According to their study, nearly three-quarters of river dwellers reported that they and/or their encampment members practice open defecation, compared to just over a third of non-river dwelling respondents. A study by Pinongcos et al. (2022) found human fecal material from ground surfaces be washed into urban waterways of the San Diego River, pointing to nearby homeless encampments, and open defecation happening there, potentially contributing to microbial contamination of urban streams (Verbyla et al., 2021).

Open defecation may have detrimental effects on the physical, mental, and social well-being (Amato et al., 2022; Ares et al., 2017) of people experiencing homelessness, and on overall public health and disease exposure (Bartram and Cairncross, 2010; Mara et al., 2010). Exposed faeces may contain harmful pathogens posing a significant threat to public health, especially among unhoused persons living near open defecation sites (Amato et al., 2022). When studying open defecation sites and analyzing stool samples, Capone et al. (2018) found 23% of analyzed stools tested positive for one or more enteric pathogens such as enterotoxigenic *Escherichia coli*, *Giardia* spp., norovirus, and *Salmonella* spp.

According to a study conducted in Los Angeles, United States, time matters in terms of sanitation access: people experiencing homelessness for a long time encountered more difficulty accessing toilets than those experiencing homelessness for a short time. The authors also found racial differences in access to sanitation services, with unhoused people

identifying as White facing larger challenges than people who identified as Black/African American and Latinx. The latter struggled with racial discrimination when accessing public toilets (Portillo et al., 2022).

A study among people experiencing homelessness in encampments along the San Diego River, United States, found that portable bathrooms, which were installed throughout the county during the Hepatitis A outbreak in 2017 and which at first sight appear to be a low-cost, easy, quick and effective sanitation solution for people experiencing homelessness, were actually not preferred. These services may not effectively reach the river-dwelling population, and entail maintenance and security issues, illegal activities such as drug use and prostitution, unless they were monitored 24/7 by private security, which was perceived as costly and unfeasible (Verbyla et al., 2021).

Finding a toilet while living on the streets is challenging, as reported by a man experiencing homelessness in Sacramento, California, United States. He describes that being thirsty, hungry or having to pee have to be planned well in advance and come at a cost, thus, to better carry money to be able to access a restaurant or coffee shop, buy a cup of coffee and food, and use the toilet, then filling up the water bottle there. Knowing and planning when to relieve themselves will help them be close to a toilet that is accessible once it is needed. He reports that often, people experiencing homelessness are denied access due to their appearance. Open defecation or wild peeing is not a good alternative – as it is dehumanizing, comes with fines or other forms of legal consequences, and as there are no handwashing options, leading to adverse health impacts and disease risk, as well as emotional and mental ill-health. According to his experience, cities and counties implement policies that worsen the access to water and sanitation by leaving water fountains in disrepair and closing public toilets throughout the night (Feinstein and Daïess, 2019).

3.4.3. Hygiene

The ability of people experiencing homelessness to maintain an adequate level of hygiene is constrained by the facilities available for their use (Leibler & Nguyen, 2019). Shelters and rehabilitation centres may offer access to showers and tap water for personal hygiene, bathing and washing, as well as laundry services, during opening hours (Portillo et al., 2022). According to Flanigan and Welsh, accessing showers is difficult for people experiencing homelessness, with very few individuals (<5%) taking showers at shelters. A study by Ho et al. (2007) revealed that in the District of Columbia, United States, showers in shelters are often not wheelchair accessible and unsafe for use. Showers often fail to provide hot water, continuous water supply, space for wheelchairs to enter, provide grab bars for wheelchair users, and that resulted in homeless adults with disability refraining from use. In Boston, Massachusetts, United States, Leibler et al. (2017) found that even if accessible, people experiencing homelessness may feel uncomfortable or unsafe using hygiene and shower services in shelters due to low levels of cleanliness or disinfection. Due to the poor hygiene conditions, people experiencing homelessness in the United States reported their health had deteriorated since moving to a shelter, and that due to poor hygiene conditions, healthcare providers refused to come to the facility (Ho et al., 2007). Feinstein and Daïess (2019) found that around 120,000 people experiencing homelessness in California were unlikely to have adequate access to hot and cold running water, and that of households (including homeless shelters) with incomplete plumbing, 14% lacked a tub or shower, associated with income and race.

Spending the days in city centres, people experiencing homelessness mainly rely on public water fountains, public toilets, water from business establishments, non-profit organizations and gas stations, and on surface waters, to practice hand hygiene in Skid Row, California, United States (Portillo et al., 2022). Water trucks often distribute hygiene products to people on the streets and, when possible, in the riparian areas of Phoenix, Arizona. Public restrooms are also used for cleaning the body, and many use sprinkler water to wash off (DeMeyers et al., 2017).

Unhoused individuals in Los Angeles lacked access to handwashing stations with soap and water where they slept (Portillo et al., 2022). Public facilities were used to refill plastic bottles with water to rinse their hands inside tents. The same study investigated menstrual hygiene management and found that numerous unhoused women reported difficulty managing their menstrual hygiene due to limited access to menstrual products and facilities where they can clean their clothing items and bathe, and coping by using toilet paper or clothing items to manage menstruation. Accessing showers was reported to be challenging too, thus, people used sinks in public parks and businesses to do a quick rinse with paper towels and water (“bird bath”) or used buckets inside their tents to shower. Excessive wait times to access bathing facilities were common, and often, facilities were not functioning. The authors found laundry services to be limited and costly, resulting in 91% of the unhoused population surveyed washing their clothing items less than three times per month. Some unhoused individuals reported that throwing away their clothes was easier than washing them.

According to Leibler et al. (2016), sleeping rough is a predictor of poor hygiene practices among people experiencing homelessness in the United States. People living in encampments or sleeping rough in Arizona have only few options for showering services, which operate only for a few hours a week. To shower, a person usually has to be aware of the times of operation, be able to reach the location, and, if needed, have the ability to wait in line for a period of time until a shower is available. Also for those who do not reside in a formal sheltering system, laundry services are limited to one location (DeMeyers et al., 2017). River water is commonly used by people experiencing homelessness in riverine encampments for personal hygiene, bathing and swimming (Donovan et al., 2008; Verbyla et al., 2021). People experiencing homelessness in the United States also frequently access emergency departments to access hygiene facilities (Kyper et al., 2022). People experiencing homelessness also used homes of friends and family members for showering and laundry, as evidenced in a study conducted by Leibler et al. (2017) in Boston, Massachusetts, United States. In Los Angeles, hygiene access among unhoused individuals varied by gender, with males experiencing discrimination more often when trying to access showers, compared to women (Portillo et al., 2022).

Hygiene was also mentioned in the literature in the context of insect or vermin infestations (e.g. cockroaches, bed bugs), which were reported widely in a study by Rosenthal et al. (2022). Limited hygiene among people experiencing homelessness is associated with a variety of communicable and non-communicable disease outcomes, including ectoparasite infestation (i.e., body lice, fleas, head lice, and scabies), which can transmit vector-borne infectious agents, including *Bartonella quintana*, *Rickettsia akari* and *Yersinia pestis*. Besides, limited hygiene can cause skin infections (Portillo et al., 2022) and methicillin-resistant *Staphylococcus aureus* (MRSA) (Leibler et al., 2017), and has been found to contribute to reduced mental health and well-being among people experiencing homelessness (Leibler et al., 2017; Rosengard et al., 2001). Personal hygiene and self-care, particularly access to regular showering and clean clothing, may also increase likelihood of transitioning out of homelessness (Leibler et al., 2017).

3.4.4. Waste management

Only few studies included information on garbage disposal and waste management in the context of urban homelessness, and despite the impact that inadequate garbage disposal can have on water quality, hygiene and health, the evidence presented was scarce overall. Literature related to sanitation touches upon waste in terms of cleanliness and hygiene in sanitation facilities, reporting that public toilets are often unsanitary, with trash accumulating in corners, floors being dirty (e.g. Felner et al., 2020), thus, indirectly mentioning the absence of functioning waste management services.

Donovan et al. (2008) address the health risks that waste, wastewater and the related exposure to pathogens create in the Lower Passaic River of New Jersey, United States, for people experiencing homelessness that

reside in encampments and rely on surface water sources. Fecal contamination in an urban watershed of the San Diego River with risks for those camping at the riverbanks are reported by Steele et al. (2017). Klein and Riemer (2011) find people experiencing homelessness in urban areas of Waterloo, Canada care for the way that litter, pollution and garbage is being handled, calling for a healthier behaviour related to waste disposal – particularly by housed people. The use of foodstuff from waste containers for consumption, and the related exposure to disease, is described in a study from Lisbon, Portugal (Moreira Marques et al., 2020), and Rosenthal et al. (2022) report infestation, vermin and pests resulting from a lack of hygiene and inadequate provision for storing household waste in shelter environments in London, United Kingdom.

3.4.5. Natural water resources

Owing to the scarcity of water provided by public services to meet basic needs, many people experiencing homelessness frequently utilize natural water resources. Flanigan and Welsh (2020), state that “wherever there is water, there are encampments [of people experiencing homelessness]”. Frequent use of urban waterways for bathing – besides showers in shelters – was reported, as access to waterways was not tied to opening hours or waiting lines. Toothbrushes, towels, and soap found by wetlands supported this claim of use of wetlands for personal hygiene (Palta et al., 2016). Waterways also may serve for fetching water, washing, bathing, fishing, cooking, and cooling, while providing a peaceful and calming environment in nature (DeMeyers et al., 2017; DeVuono-Powell, 2013; Palta et al., 2016).

Apart from using natural water resources to help meet basic needs, these resources also offer protection from environmental elements and perceived danger, providing a sense of security and privacy. According to Palta et al. (2016), by the Salt River in the United States, people experiencing homelessness are exposed to social and biophysical stressors while possessing limited capacity to mitigate them. They might thus access and use ecosystem services in unconventional ways. Particularly in drier climates, where dense vegetation, shade and water access are scarce resources (Sanchez, 2011), Water ecosystems provide regulating, cooling services from evaporative cooling or shade or both, constituting a coping mechanism and supporting health and well-being for people experiencing homelessness, particularly on hot days. Palta et al. (2016) found shade and cooler temperatures around water bodies attract people experiencing homelessness to spend (part of) their days there, to cool off and to put the feet in the water on warm days. Besides providing various ecosystem services and supporting well-being, water bodies offer protection from public view (DeVuono-Powell, 2013; Flanigan and Welsh, 2020), protection from law enforcement and perceived dangers, a sense of security and privacy. They allow relaxation in a peaceful quiet environment in nature, away from the city environment where shelters are located, that people experiencing homelessness enjoy using for reading and napping (Palta et al., 2016).

3.4.6. WASH challenges faced by women experiencing homelessness

Women appeared to be a particularly vulnerable subgroup of people experiencing homelessness. In Skid Row, Los Angeles, United States, the self-reported hygiene of women experiencing homelessness varied and was strongly affected by the type of homelessness. Those sleeping rough reported very poor hygiene not only because of a lack of accessible water, toilets and showers, or the inaccessibility of existing WASH infrastructure (Baldwin, 1998). Public toilets available to people experiencing homelessness are often not sex-segregated, and often lack menstrual hygiene products, soap, paper towels, toilet paper and seat covers, as well as privacy, and were often not clean - all of which are vital for menstrual hygiene management (Ares et al., 2017). Specific empirical findings on menstrual hygiene management and related challenges among women in encampments or shelters could not be identified based on our systematic scoping review design, or previous reviews (Moffa et al., 2019). Boden et al. (2021), exploring menstrual hygiene management for vulnerable communities, found women

experiencing homelessness face challenges related to a lack of period products available to them, and in terms of stigma associated with menstruation while homeless. Menstruation complicates the life of women experiencing homelessness – and planning already unplannable days - with WASH infrastructure and menstrual products inaccessible, women having to cope with period-related pain, and sharing resources in shelters where they experience a lack of privacy - even further. While they might be able to find period products for free or at reduced price in shelters, available products were often of low quality, shelters distant requiring long travel times, long waiting times in line, and accessible only during specific times, women were often forced to make menstrual hygiene management a cost-benefit analysis. Avoiding social contacts during menstruation, and hiding their period was a common strategy resulting from inadequate menstrual hygiene. Shelter facilities available to women have been described as inadequate, and not suitable for women's needs, in terms of both physical space and habitability (Baldwin, 1998). Female only shelters or shelter rooms and beds, showers, sanitation facilities are few, and not satisfying demand, and privacy rarely exists. As outlined in this review, with toilets not being available at all, or inaccessible at night, open defecation is often the only sanitation option for people experiencing homelessness. For women, this practice comes with extra challenges while menstruating, with an experience of, which is exacerbated when men see them urinating or defecating in public, while also bearing additional risk of gender-based violence, sexual harassment and violence when they travel to and from open defecation sites, especially at night (Frye et al., 2019).

According to a study among women experiencing homelessness, 66% of surveyed homeless women took a shower, 89% of women brushed teeth and 61% changed clothes every day in week preceding the study. When ranking health-related concerns, a major issue addressed by women experiencing homelessness was taking a shower (Rosengard et al., 2001). Baldwin (1998) explained poor hygiene among women experiencing homelessness was often a combined result of a lack of access to toilets and a breakdown of both physical and psychological resources. Those residing mainly in shelters tended to have better hygiene than those sleeping rough, though not always, with fluctuations associated with the state of physical and mental health. In addition, women experiencing homelessness would “use” poor hygiene as “a conscious and articulated defense” against males.

3.5. Extreme weather events, WASH and health among people experiencing homelessness

People experiencing homelessness are a vulnerable population susceptible to adverse health effects from extreme weather (Cusack et al., 2013; Kidd et al., 2021a,b), with comorbidities that make them particularly vulnerable to adverse effects of extreme weather events, ranging from poor physical and mental health issues and side effects of associated medications, and drug and alcohol dependencies (Every et al., 2021). Weather-related morbidities pose a disproportionately higher risk to people experiencing homelessness as they spend significantly more time outdoors (Aldridge et al., 2018).

3.5.1. Heatwaves

During heatwaves heat-related illnesses and death are posing a disproportionately higher risk to people experiencing homelessness because of the time spent outside, the continuous exposure to rough environmental conditions and outdoor day and night temperatures. Most people experiencing homelessness are without access to air-conditioning (English et al., 2022), have low adaptive and coping capacity, and limited access to adequate quantity of safe water for hydration and cooling (Cusack et al., 2013; Palta et al., 2016; DeMeyers et al., 2017) and healthcare service provision (Nicolay et al., 2016). Water insecurity during heatwaves can not only result in dehydration, sunburn, heat exhaustion, heat cramps, and heat stroke, but also deteriorate (often already low) status of mental, physical (respiratory or

cardiovascular disease, high blood pressure, diabetes, hypertension, kidney failure), and social health (lower social status), and reduced health promotion as a consequence of reduced hygiene, and death (Cusack et al., 2013; DeMeyers et al., 2017). Besides, a rise in insect bites leading to increased skin and vector-borne infections has been reported. Effects of extreme heat may be amplified where direct exposure cannot be avoided, which is often the case for people experiencing homelessness mostly living in metropolitan cities where finding cool space is particularly difficult as the built environment retains heat (English et al., 2022). DeMeyers et al. (2017) found that lack of vegetation, urban heat island effect, and lack of WASH services are all factors that increased the risks of dehydration and heat exhaustion for unhoused people in Arizona. Heat-related health risks are aggravated by the complex interactions between mental illness, medications and substance use disorder (English et al., 2022).

A study by Portillo et al. (2022), examining WASH access among unhoused communities, coping with water insecurity, and access to WASH services and determinants in Skid Row, Los Angeles, California, United States, for example, found 34% of unhoused people reported dehydration due to lack of enough water intake. Every et al. (2021), when investigating experiences of heat stress in Adelaide, Australia, found that while the majority of rough sleepers interviewed reported drinking a litre or more water (2.5–3 L are recommended) in the 24 h preceding the survey, more than half still felt thirsty and almost 80% experienced one or more heat stress symptoms. Judging based on their urine colour, 81% were appreciably dehydrated. Lack of, or limited access to drinking water was a major concern to people experiencing homelessness, as were sunburn, dehydration and other heat-stress symptoms. Similarly, Wandel et al. (2010) found that during extreme heat, people experiencing homelessness in Cambridge and Kitchener, Waterloo, Canada, struggle to stay hydrated, as access to potable water is limited by too few functional public water fountains. Likewise, finding shelter from the sun is challenging. In Adelaide, Australia, people experiencing homelessness identified several issues that challenged regular access to drinking water, despite regular supplies of bottled water by service providers during heatwaves. Challenges included petrol stations and municipal taps removing handles to prevent water access, public water fountains in disrepair, and access to water via public toilets limited overnight. During heatwaves, the City Council made major efforts to reduce water usage, which complicated access to drinking water further for people experiencing homelessness (Cusack et al., 2013).

With access to water being limited, to deal with heatwaves, and to avoid heat-related illness, people experiencing homelessness respond as best as their living conditions, circumstances and capacities allowed. Coping strategies that were adopted included attempting to drink more water, seeking shade shelter and refuge in air-conditioned buildings and public transport, wearing one layer of permeable clothing (Every et al., 2021), and soaking clothes with water to maximize evaporative cooling, using garden hoses from residents' homes, using bathrooms in public places such as malls, or free water from restaurants (Wandel et al., 2010). In Phoenix, Arizona, United States, volunteer groups and NGOs operated water trucks and heat-relief donation spots during the day for rough sleepers during heatwaves (DeMeyers et al., 2017).

Waterways are an important health-promoting resource for people experiencing homelessness during heatwaves and in hotter climates in general, as they provide important shade and temperature regulating benefits, (Palta et al., 2016). Spending considerable amounts of time in such encampments, however, residents risk exposure to harmful plants, insect bites, and snake bites, water-related diseases, and dehydration due to the distance from sources of safe drinking water and the need to haul drinking water into riverbed encampments (DeMeyers et al., 2017).

According to Cusack et al. (2013), finding a cool spot in the inner-city area of Adelaide, Australia, can be challenging. The surrounding parklands are commonly used as refuge by people experiencing homelessness during extreme heat, as are air-conditioned public places such as libraries, or shopping malls – where they were, however, often not

tolerated. In response, they requested longer access hours from homeless services, and are granted additional shelters and access to an air-conditioned bus station by the City Council. According to the same study, the combined lack of easy access to cooling centres and drinking water exacerbates the already poor health of those living rough, and those with mental health issues and substance use disorders are consistently identified as groups to be most concerned about. In Waterloo, Canada, when a heat alert is issued once the temperature rises above 30 °C, feeling above 40 °C due to the combined effect of heat and humidity, cooling centres come into effect and include pools, community centres, libraries and other City facilities where community members can cool down and have access to drinking water (de Gómez, 2010). In Adelaide, Australia, homeless and health service providers pro-actively engage with people experiencing homelessness during heatwaves to monitor their health, remind them to wear appropriate clothing, access cooler environments and drink more water – particularly to those affected by mental health issues, as their capacity and ability to self-care and adjust their behaviours to environmental changes are reduced (Cusack et al., 2013).

3.5.2. Flooding, heavy rain and storm

Flooding, heavy rain and storms pose a serious hazard to people experiencing homelessness, particularly to those staying at riverine encampments, and especially in drier areas where flash flooding following storms is common, as found in Contra Costa county, California, United States (DeVuono-Powell, 2013). Living in tents and shacks, directly exposed to the forces of nature, with limited or zero protection, not only are they at risk of water-related diseases, injury and death, but at risk of losing their equipment as well. In their study among people experiencing homelessness in Cambridge and Kitchener, Waterloo, United States, Wandel et al. (2010) found that rain, and sudden rainstorms in particular, were the most frequently mentioned problem as finding shelter and storage for belongings in time, getting soaked, struggling with wet gear, lacking appropriate footwear and getting caught in flooding was challenging. de Gómez (2010) detailed the problematic related to rain for people experiencing homelessness in the Waterloo region, Canada, as tents and sleeping bags got wet, and as people experiencing homelessness had very few free places they could go to dry, and reported trench foot, colds, flus, pneumonia and mental health issues as a consequence to wetness. To cope with rain, besides searching for shelter, people experiencing homelessness used public spaces such as the libraries, shopping malls, restaurants, coffee shops, bus terminals and food banks not to get wet, or took shelter under bridges, loading docks, awnings, and in trucks, cars, and emergency exits (Wandel et al., 2010). DeVuono-Powell (2013) found encampments prone to floods posing risks to human health, as flood waters, and garbage accumulated in them, were associated with water- and vector-borne disease risks (Ramin and Svoboda, 2009).

Donovan et al. (2008), evaluating risks of pathogen-related disease associated with combined sewer overflow discharges into the Lower Passaic River in New Jersey found fecal concentrations in urban waterways, which were – among other sources – associated with homeless populations residing at the riverbanks, to be greater during storm events. Similarly, Steele et al. (2017) reported the presence of fecal contamination in an urban watershed of the San Diego River at 13 different sampling locations during wet weather and storm events, with direct deposition from homeless populations residing in encampments at the riverbanks being one of the potential sources.

3.5.3. Cold

Cold-related conditions, and injuries due to frostbite or hypothermia can cause severe morbidity or death, and they represent a serious public health issue. People experiencing homelessness have greater exposure than the majority population. According to Zhang et al. (2018), in Toronto, Canada, a Cold Weather Response Plan exists, and extreme cold weather alerts are issued when the weather forecast predicts a

temperature of -15°C or colder or a wind chill of -20°C or colder. In Waterloo, Canada, a cold weather protocol comes into effect between November and April each year when temperatures of -15°C or lower are forecasted, along with wind chill and/or freezing rain (de Gómez, 2010). According to Cusack et al. (2013), adverse health effects from the cold become prevalent when mean temperatures fall below 11°C . In regions relatively unaccustomed to very cold winter weather, near freezing temperatures are considered 'extreme cold'.

A study conducted by Anderson et al. (2021) examining associations between biophysical and social environments and self-reported general health and emotional well-being in Nashville, Tennessee, United States, found unsheltered homeless people reported the lowest general health scores during winter months.

Many temporary accommodations for people experiencing homelessness are not equipped for cold winter months. Windows may be broken, and/or boilers causing excessively cold temperatures as found by Rosenthal et al. (2022) who describe the indoor environmental health barriers among children experiencing homelessness in temporary accommodation in London, UK. According to this study, shelter residents used cellophane tape to patch up windows to keep the cold air from coming in and where, regardless of this coping mechanism, the indoor temperature was excessively cold, and comparable to the outdoor temperature $5/6^{\circ}\text{C}$. Resulting dampness and mold had detrimental impacts on the residents health, increasing the risk for respiratory conditions of flu, pneumonia, bronchitis, allergies, asthma, exposure to toxins from mold and fungal infections, cardiovascular conditions of heart attacks and strokes and potential threats to mental health and social wellbeing. In a study by Winkleby (1990) examining health risk factors among people experiencing homelessness in San Jose, California, extremely poor living conditions were reported, with large disparities in access to heated rooms, running hot water, and cooking facilities existing between the sheltered (15% lacking access) and non-sheltered poor (90% lacking access), all of which are particularly problematic during periods of extreme cold. In Cambridge and Kitchener, Waterloo, Canada, Wandel et al. (2010) found that during extreme cold, low temperature, and snow, compounded by wind, were frequently mentioned as a major challenge as it affected both damage to gear (tents) and a person's body. Sudden snow storms were particularly difficult to deal with, as people experiencing homelessness lacked appropriate footwear to avoid wet feet. Cold was found to have negative effects on physical and mental health, resulting in frequent colds, pneumonia, and kidney and bladder infections.

Homeless people in Adelaide, Australia reported a higher incidence of illness during cold weather, with respiratory issues as the most common complaint, and increased prevalence of foot conditions, such as infected sores on toes, being a major challenge as well. Keeping clothes, footwear and bedding dry was a major issue reported by homeless participants. To reduce health-related risks during cold for people experiencing homelessness, more secure places to store essential clothing and bedding, provision of a foot care clinic as well as access to dry socks and shoes, and coordinated, targeted information campaigns were proposed before winter sets in (Cusack et al., 2013). Hygiene was addressed in the context of foot care and cold in a study by Chen et al. (2014) in San Francisco, United States, where those unable to perform foot hygiene in terms of frequent changing shoes and socks, regular toenail trimming, washing their feet were at higher risk of frostbite, and immersion foot and skin lesions during periods of cold.

In Waterloo, Canada, in order to deal with colds, offers such as the Out-of-the-Cold program were used, and besides, if possible, people stayed in public buildings (e.g., libraries), empty moving trucks, emergency exits or at friend's houses, wore at once all pieces of clothing they possessed, with unpleasant and problematic consequences if they get wet (Wandel et al., 2010). To gain access to a warm place to stay, e.g. get into a shelter, or even into jail, some people experiencing homelessness tried to be admitted to residential alcohol and drug rehabilitation programs or committed minor crimes. Measures to support people

experiencing homelessness during cold include the opening of emergency warming facilities, 24 h drop ins, relaxed shelter restrictions, increased number of shelter beds, provision of enhanced (WASH) services by local agencies, dissemination of information and advice on how to prevent hypothermia and additional outreach. Weather- and health-related information is available to persons experiencing homelessness to reduced cold-related health risks (Zhang et al., 2018).

4. Discussion

4.1. Extreme weather events, WASH and disease exposure among people experiencing homelessness

Our systematic scoping review aimed to fill the combined knowledge gap of understanding the WASH insecurity challenges that people experiencing homeless in urban areas in high-income countries are facing, particularly during extreme weather events. It showed that there are many different forms of homelessness, and that people and communities experiencing homelessness, and types of homelessness vary, including rough sleepers, people staying at shelters or in encampments, with friends, or a combination of these. Likewise, there are many different subpopulations of people experiencing homelessness (e.g. women) (Moffa et al., 2019), with different challenges that they are facing, and different needs in terms of WASH. Where someone experiencing homelessness stays, where and when they access WASH-related services, varies over space and time.

People experiencing homelessness are one of the most vulnerable groups in a society, often suffering from ill-health in terms of chronic diseases, mental health issues and reduced well-being, and often struggling with substance abuse and stigma (DeMeyers et al., 2017). Living in poverty and with limited access to vital resources, with no stable housing, challenged in spending their days on trying to meet their food, shelter, water needs, people experiencing homelessness commonly bear a higher burden of infectious diseases too (Flanigan and Welsh, 2020). These conditions make access to safe public WASH even more important to them than for the general population (Flanigan and Welsh, 2020). As shown in this review, however, people experiencing homelessness – depending on the services publicly provided – face major barriers in accessing safe WASH – with public water fountains often dysfunctional or shut down, especially in winter; with public toilets being too few, too unsafe, too unclean, too poorly equipped, too expensive, leaving often no other option but open urination and defecation; with handwashing facilities not being available, lacking water, soap and towels; with public showers lacking altogether, or use being tied to reserving a timeslot or waiting lines, and cost.

Existing problems, health- and WASH-related challenges are exacerbated and further complicated during extreme weather events (Wandel et al., 2010), as during heatwaves, public water is rationed; during flooding, public restrooms and services might be inaccessible; during periods of extreme colds, water supply is shut off. At the same time, the burden of disease is increased during extreme weather events (Cusack et al., 2013), and therefore, better access to WASH is needed: during heatwaves, more water for hydration and cooling is needed to avoid heat-related conditions such as dehydration and heat stroke (Every et al., 2021); during periods of extreme cold, more hygiene is needed, to avoid cold-related dermatological conditions, e.g. on the feet; and during heavy rains and flooding, and warmer climate, there is an increased incidence of water- and vector-borne diseases, thus, to avoid contact (Ramin and Svoboda, 2009), more access to drinking water, to hygiene and to sanitation is needed. While extreme weather events created additional needs and hardships for people experiencing homelessness (Ramin and Svoboda, 2009), likewise, they impact on, and reduce, the service providers' abilities to deliver extra relief at these particular times (Cusack et al., 2013), thereby creating a dual (WASH and health) burden to this vulnerable group.

Extreme weather events significantly shape the daily experiences of

people at risk of homelessness (Every and Richardson, 2017; Walters and Gaillard, 2014), and with the frequency, intensity and unpredictability of extreme weather events predicted to increase (Anderson et al., 2021; Every et al., 2021; IPCC, 2022), understanding these links between WASH insecurity, climate resilience and homelessness is more important than ever. While the literature included in this review offered some in-depth insight into the implications of heatwaves on WASH, and the related challenges, little insight into implications of periods of extreme cold, rain, storm and flooding could be identified.

In order to fill the combined knowledge gap on challenges that homeless communities in urban areas in HICs are facing with regard to WASH insecurity overall, and specifically with regard to accessibility and usability of WASH during extreme weather events, we operationalized the complex links based on the literature reviewed, which is displayed in the Climate-Resilient WASH for Homeless Framework (Fig. 2). It represents and simplifies the linkages between WASH, weather and homelessness, leads to an improved understanding of the underlying complexities, and provides the basis for improved preparedness.

4.2. The human right to water and sanitation for people experiencing homelessness

Water and sanitation are fundamental to the health, dignity and prosperity of all. Access to water and sanitation is a human right, as formally recognized by the United Nations General Assembly in 2010 (United Nations, 2015a). The Human Right to Water and Sanitation (HRTWS) is directly addressed in the 2030 Agenda for Sustainable Development through Sustainable Development Goal (SDG) 6, which aims to *ensure availability and sustainable management of water and sanitation for all* (United Nations, 2015b). According to the WHO/UNICEF Joint Monitoring Programme, which publishes global estimates of WASH coverage in households, schools and healthcare facilities, billions of people globally lack access. According to these official estimates, lack of access is widespread mainly in low- and middle-income countries, and people in HICs are reported to have nearly universal access to WASH. While one might assume that WASH services are available to people experiencing homelessness in HICs, with according to the 2019 WHO/UNICEF JMP report, basic water, sanitation and hygiene access for urban persons in high-income countries greater than 99% in most countries (Supplementary file 3; WHO and UNICEF, 2019), studies documenting associated findings did not support this assumption and show that the reality is far different from these estimates. A systematic scoping review of hygiene behaviours, environmental health conditions and associated health outcomes in homeless shelters by Moffa et al. (2019) analyzed 28 studies and found evidence related to WASH in shelters was rather scarce, with only two of these studies (7%) discussing concerns regarding drinking water and sanitation in shelters, including occasional water shortages and barriers to bathroom usage such as prohibitive cost or wheelchair inaccessibility, insufficient water quality, and lack of toilets. More than half of the included studies indicated sheltered homeless persons were able or encouraged to shower, while other studies noted showers were often broken, without water, or not wheelchair accessible. About one third of studies noted shelters provided laundry. One third of studies investigated personal hygiene of shelter residents. The study found some homeless shelters to be operating at full capacity nightly (Badiaga et al., 2008), over capacity frequently, especially in adverse weather conditions, and overcrowding to be associated with increased person-to-person infectious disease transmission, while failing to infectious clients (Moffa et al., 2019). People experiencing homelessness live with the daily challenge of accessing sanitation and hygiene services, clean showers, laundry and hand washing facilities (Leibler et al., 2017). WASH insecurity affects people experiencing homelessness in different living conditions (sheltered, in encampments, sleeping rough) differently (DeMeyers et al., 2017). In order to achieve SDG 6, there is a long way to go particularly

for vulnerable groups in high-income countries, such as people experiencing homelessness.

The normative content of a HRTWS relates to the availability, accessibility, affordability, acceptability and quality/safety of water and sanitation (Flores Baquero et al., 2015; Frye et al., 2019; Giné-Garriga et al., 2017; United Nations, 2010, 2014). *Availability* relates to improved sanitation, a sufficient number of facilities for the amount of people they are supposed to serve, and includes individual and/or shared use of facilities. According to literature included in this review, WASH is often not available to people experiencing homelessness as per the HRTWS. Capone et al. (2020), for example, in their study on urban homelessness in the United States estimated that at least 0.29% of residents ($n = 930,000$) in US cities lacked access to at least basic sanitation - an estimate that is substantially greater than the 0.01% of urban persons ($n = 28,000$) that the JMP reported as having limited sanitation, having unimproved sanitation. The Sphere standards for sanitation in long-term refugee camps, endorsed by the United Nations High Commission for Refugees, state that there should be at least one toilet for every twenty persons, and that no person should be dwelling further than 50 m from a toilet (Amato et al., 2022; The Sphere Handbook 2018). The reality in neighbourhoods where many people experiencing homelessness stay, however, is by far different. *Acceptability* covers cultural issues related to the service provided, privacy and gender issues. Several studies included in this review reported on women experiencing homelessness being left behind in terms of WASH, as, for instance, public WASH infrastructure is not sex-segregated, shelters are not sex-segregated or do not offer separate spaces and hygiene facilities for different genders, and no privacy either (Ares et al., 2017). Where drinking water fountains, showers and toilets in urban areas do not exist, using water from fire hydrants or hoses for bathing and drinking, urinating and defecating in buckets or plastic bottles, and open defecation are widespread coping mechanisms (Portillo et al., 2022), none of which are acceptable either. *Affordability* entails a reasonable price of sanitation services for all, which is not guaranteed for people experiencing homelessness either. In fact, many rely on public toilets that are not free of use, on buying bottled water, on paying for shower use or hygiene products, which places a financial burden on them. *Accessibility* calls for reliability in terms of access, and access to facilities at all times of day and night, with reasonable waiting times. Accessibility also relates to a safe and convenient path as well as easy-to-use and adapted technology. WASH infrastructure available to people experiencing homelessness, whether in shelters, businesses, and even public toilets, does not operate 24/7, and water trucks provided on days of extreme heat do not either, as both are usually linked to fixed opening hours or a concrete schedule, which creates a barrier to universal use by people experiencing homelessness (DeMeyers et al., 2017). Besides, for someone with a low level of hygiene, as is often the case for people experiencing homelessness, entering a business or a restaurant to make use of a restroom is often perceived as unacceptable, and comes with discrimination, stigma and maybe even rejection of being allowed in businesses. *Quality and safety* refers to technical and hygienic safety of facilities, access to water for handwashing and other hygiene practices, menstrual hygiene management, hygienic cleaning and emptying of pits; safe management and disposal of human urine and faeces. Our review shows that public toilets, showers and water fountains available people experiencing homelessness are often unsafe, dirty, unmaintained, and understaffed, and thus, unsafe (Amato et al., 2022; Ares et al., 2017). Negative experiences in and perceptions about unsanitary, smelly, dirty, overused, unmaintained and unflushed public toilets also affect the willingness of use (Frye et al., 2019). Where sanitation is not available when and where it is needed, open defecation is the only option to many people experiencing homelessness in urban areas (Amato et al., 2022; Capone et al., 2018), resulting in the human right to sanitation for this vulnerable group not realized and valid concerns about the risks of related infectious disease transmission (Frye et al., 2019). Among those living in deeply hidden landscapes such as waterways, wetlands and riverine

encampments, surface water sources being used for bathing, washing, and drinking, and open defecation is common. The water may be contaminated and polluted, exposing people experiencing homelessness to poor water quality, mosquitoes and other disease vectors (Palta et al., 2016) associated with infectious diseases.

While often not the primary focus, SDG 6 also addresses solid waste disposal. Effective waste management and proper garbage disposal play a critical role in safeguarding the health and hygiene of homeless populations. Despite their vulnerable circumstances, access to sanitary waste disposal services is paramount to prevent the spread of diseases, contamination of water sources, and degradation of living conditions. Adequate solid waste management not only ensures a cleaner environment but also minimizes the risk of illness and infections associated with unhygienic surroundings. Paradoxically, despite its vital importance, there remains a notable scarcity of literature addressing this crucial aspect of homeless well-being. The lack of comprehensive research underscores the need for increased attention and concerted efforts to bridge the gap in understanding the pivotal role waste management holds in promoting the health and dignity of those experiencing homelessness.

Safeguarding the HRTWS for people experiencing homelessness is particularly important considering the scarcity of shelters and services in smaller communities. People experiencing homelessness are often driven to delinquent behaviour due to their living conditions. The correlation between homelessness and crime (Burton et al., 2018) is especially significant when mental illness is present (Roy et al., 2014). In addition to these struggles, the exhibited behaviour – whether intended or not – can lead to bans or exclusion from emergency homeless services such as shelters. A study by Kerman et al. (2022) found that recent involvement with the criminal justice system predicted shelter bans. While some are actively excluded from the use of emergency homeless services, others are passively excluded if not meeting the entry requirements (e.g. due to substance abuse disorder, citizenship, residential status). If WASH access relies on shelter services, automatically, certain groups of people experiencing homelessness are excluded. WASH access as a human right, however, obligates governments and communities to ensure it for everyone, regardless of their access to other services.

For people experiencing homelessness, limited access to drinking WASH facilities and resource constraints at existing facilities present challenges to maintaining dignity, health and privacy, hampering the realization of the HRTWS for them (Leibler et al., 2017; Portillo et al., 2022). The implications of a missed realization of the HRTWS for people experiencing homelessness have far-reaching consequences, making it harder to transition out of homelessness. When there is no toilet or shower to be used, not only hygiene and appearance are degraded, but also is the feeling of self-worth, physical and mental health, all of which make it more difficult to apply for and get a job, housing or services needed (Ares et al., 2017).

4.3. *The most vulnerable of the vulnerable: women experiencing homelessness*

Women represent a highly vulnerable, and fast growing group among people experiencing homelessness (Anderson et al., 2021; Baldwin, 1998; Debska and Mosowska, 2021; Rosengard et al., 2001), while representing one of groups most vulnerable to climate change (Costello et al., 2009). However, little remains known about their adaptation to the challenges associated with WASH, extreme weather and homelessness. According to Baldwin (1998), women experiencing homelessness face similar – but amplified – concerns as their male counterparts, and as the results of our scoping review have shown, access to WASH infrastructure for women experiencing homelessness is of major concern.

Extreme weather events are likely to deteriorate WASH security among women experiencing homelessness. As described in this review, during heatwaves and periods of extreme cold, water from public taps and fountains is often turned off or rationed, and less accessible to

people experiencing homelessness. During periods of heavy rain, storm and flooding, (surface) water sources may be contaminated, exposing those relying on them, and using them for drinking or for hygiene, to water-related infectious diseases. With less quantity and quality water available, less hygiene is possible too, also exposing to water-related infectious diseases. Overall, it can be assumed that (even) poor(er) WASH due to extreme weather events will affect those already suffering from WASH insecurity the most, reduce their health-promoting potential, exacerbating their already physical, mental and social health (Anderson et al., 2021).

4.4. *Prioritization and needs among people experiencing homelessness*

People experiencing homelessness (have to) invest substantial energy and time in obtaining food, shelter, places to rest and sleep. Health promotion and the fulfilment of basic health needs – including WASH – is often only satisfied once these more immediate “survival” needs have been met (Nickasch and Marnocha, 2009). Besides, mental health issues and substance use, which have been found to be widespread among people experiencing homelessness, and correlated with poor hygiene and sanitation and thus, increased disease risk, complicate things further (Leibler et al., 2016).

With their usually complex, wicked, dynamic, unstable, unpredictable and challenging life realities, a lack of storage and difficulty of taking care of their possessions and the discrimination they are subject to, people experiencing homelessness have an external locus of control, relying on services provided to them, and lack resources – and thus also priority – to meet their physical needs of accessing sanitation, hygiene and health resources if not already offered to them (Baldwin, 1998; DeMeyers et al., 2017; Kyper et al., 2022; Nickasch and Marnocha, 2009). Challenges include affordability, including cost for bottled water, toilet use, (menstrual) hygiene products, medical visits (considering that many individuals are not health-insured); availability of needed resources, ranging from lack of a home address needed for paperwork, and lack of assistance with paperwork to setting up services or appointments, e.g. for using a shower in a shelter (Nickasch and Marnocha, 2009).

People experiencing homelessness are subject to environmental injustice (Klein and Riemer, 2011), occupying central and marginalized urban areas that pose environmental hazards, such as the poor water quality, flooding, urban heat island effect, a lack of vegetation, and a lack of adequately maintained public parks. Water and WASH insecurity does not come as a stand-alone problem to them, but is interconnected with the exposure to extreme conditions and ill-health. Compared to such other pressing needs, hygiene, water, and sanitation may not be the most important priority. Similarly, pre-existing diseases and ill-health related to extreme weather, e.g. heat-related lethargy or mental illness, can cause individuals not to prioritize putting efforts in accessing safe water (DeMeyers et al., 2017).

Many people experiencing homelessness struggle with addiction and substance abuse, and these have major implications on individual priorities. Someone who is looking for money to satisfy their addiction might not have (or take) the time to queue up for a shower and take care of their personal hygiene. Personal priorities underline the need for local governments to create easy and widespread access to WASH to avoid exclusion of already struggling groups.

Another important aspect in the context of addiction and WASH is that the access to clean water can be considered a harm reduction strategy for substance users. Safe water for syringe use and management can prevent the use of other, contaminated fluids, and thus, the exposure to bacterial and other infections (Harris et al., 2020). Without access to clean water, the likelihood to engage in high-risk injecting behaviours such as public injecting, syringe sharing and re-use, or preparing drugs with non-sterile water sources is increased (Hrycko et al., 2022). Although the implications of WASH for drug use goes beyond the scope of, and was excluded from this review, it is important to bear it in mind in the context of water insecurity and homelessness.

Many of the challenges that people experiencing homelessness are facing are interrelated: mental ill-health reduces the capacity and ability to self-care (e.g. take care of water needs while public fountains are in disrepair) and adjust the behaviours to environmental changes (e.g. need for more water during heatwaves); poor hygiene and lowered social status have implications on staying stuck in unemployment, making an individual more prone to long-term homelessness and the effects of extreme weather; and poor hygiene and lowered social status, cause individuals to be rejected from businesses and their WASH facilities (Portillo et al., 2022), which also is troublesome during extreme weather when these facilities are less available and accessible already to reduce water usage (Cusack et al., 2013). As such, WASH insecurity exacerbates stigmatization and social exclusion and perpetuates a cycle of poverty (Cusack et al., 2013; Portillo et al., 2022). To support them in meeting their WASH- and health-related needs, in Adelaide, Australia, service providers pro-actively connect with people experiencing homelessness during heatwaves to monitor their health, remind them to wear appropriate clothing, access cooler environments and drink more water.

The levels of dehydration and heat stress symptoms among people experiencing homelessness suggest that immediate responses could include making drinking water even more readily available (Every et al., 2021). It may be helpful to provide information which highlights heat stress symptoms including indicators of dehydration. The role of outreach in providing connections, support and advice is most likely to ameliorate the risk of heat stress. However, the long-term response to protect people from heat stress is access to housing (Every et al., 2021).

4.5. Representation of people experiencing homelessness and data gaps as a barrier to improvement

Our review included all literature published, with no date restriction. The first paper that we identified was published in 1990, and while prior to 2015, the topic was not often addressed, with only 15 published papers reporting on the context of urban WASH, weather and homelessness in HICs, 34 papers were published since 2015. This increase in publications indicates an increase in attention to the water, sanitation, hygiene, health and extreme weather events among people experiencing homelessness. Attention to underserved populations may have been bolstered by the adoption of more expansive Sustainable Development Goals related to water and sanitation in 2015 (United Nations General Assembly, 2015), as also observed regarding WASH among Roma communities (Anthonj et al., 2020b).

Not only do people experiencing homelessness very rarely have their own lobby advocating for their interests and needs, voting policies often require additional effort to participate in elections compared to the non-homeless general population. Voter registration being linked to a fixed address complicates the process (Krennerich, 2021) as well as the need for identification documents. To allow political participation for all, governments need to address the barriers that homeless people currently face as well as other aspects of exclusion experienced by this group. While the Lisbon Declaration on the European Platform on Combatting Homelessness acknowledges the social exclusion that homeless people are facing, national strategies in the member states are still underway. A key element in combatting homelessness is the stability of governments and the structures implemented to aid people experiencing homelessness regardless of the current legislative period (O'Sullivan, 2022). While the correlation between homelessness, access to WASH and climate has been studied to a limited extent (Ballard et al., 2022; Bezgrebelna et al., 2021), the national strategies implemented to address these combined and integrated challenges rarely reflect that and instead try to manage them separately.

People experiencing homelessness and the WASH- and climate-related challenges they are facing are often not well-represented in the literature, and in national and international statistics for several reasons. This highly mobile and often invisible vulnerable group is commonly undercounted in national surveys which are often based on household

units, and are therefore not explicitly included in any national estimate of water and sanitation access. Without housing, however, consistent access to improved water and sanitation when and where they are needed is almost impossible (Ares et al., 2017; Capone et al., 2020; Feinstein and Daless, 2019; Leibler et al., 2016).

Information on homelessness is not collected in a systematic manner, not on a regular basis, and might only take into account the “visible” forms – those living in shelters or other types of accommodations. Unsheltered people experiencing homelessness are more difficult to locate (Anderson et al., 2021), as are people using other forms of housing, such as sleeping rough, living in cars, “sofa-surfing” and staying with relatives or friends, living in tents, or changing between different residences (Debska and Mosowska, 2021). People experiencing homelessness are often stigmatized, criminalized, viewed as something to be kept out and invisible of central urban areas and as a consequence, pushed to hazardous environments such as riverbeds (Bonds and Martin, 2016; Flanigan and Welsh, 2020; Palta et al., 2016). There they are more socially isolated and disconnected not only from WASH and health services compared to those living in downtown areas, but also from authorities trying to collect their information. According to Anderson et al. (2021), unsheltered people experiencing homelessness in Nashville, Tennessee, United States, who may intentionally hide themselves from public view to avoid criminal charges, are not commonly captured by the annual point-in-time count. Similarly in Poland, according to a study investigating homelessness among women, the robustness of official counts has been widely disputed (Debska and Mosowska, 2021). If undercounted, not only people experiencing homelessness, but also WASH- and weather-related challenges associated with them, might not be recorded at all.

People experiencing homelessness also commonly experience stigma, social exclusion and discrimination in general, and with regard to access to drinking water, sanitation, hygiene and health (Brown et al., 2023; Kidd et al., 2021). This affects their trust towards volunteer groups and authorities intending to assist them, resulting in hesitance to accept assistance and interventions, and unwillingness to get involved in research activities and data collection – and even accepting water donations during heatwaves. Likewise, living at the margins, difficult for volunteer groups and authorities to access them, they often remain under the radar and out of reach to be involved in outreach efforts related to WASH interventions and services, preparing for the effects of – and strengthening resilience towards the effects of extreme weather events (DeMeyers et al., 2017). Thus, the systemic inequities that they are facing increases their exposure to WASH- and health-related risks, while decreasing their access to assistance to mitigate and reduce them (Kidd et al., 2021).

Information from people experiencing homelessness is scattered, and available studies often suffer from poor, non-uniform methodologies, are restricted to a small geographic area in only just one country, with small non-representative sample sizes, lack of control groups, longitudinal studies, spatial analyses and other issues, combined with ethical and logistical obstacles to data collection. The widespread lack of relevant data, as well as the variety of settings and heterogeneity of people experiencing homelessness – and even the definitions describing their lifestyles – make any comprehensive study of the topic difficult. Thus, research on WASH, weather and health issues that affect people experiencing homelessness remains underfunded, understudied, and a neglected public health concern. All of these factors have led to a paucity of published literature and detailed understanding of the needs and inequalities among people experiencing homelessness, who remain at the margins and under the radar. This poses a barrier to research, interventions and advocacy to improve their conditions.

4.6. Limitations of this review

Our complex search strategy, connecting terminology associating (i) water, sanitation and hygiene (WASH), (ii) climate, weather and climate

resilience and (iii) homelessness, and including only literature from urban settings in high-income countries, may present a limitation to identifying and including all relevant literature. The literature included in this review had pitfalls and various limitations. We did not analyze the impact of these limitations on the reliability of our results, which was beyond the scope of our study. The systematic search excluded thorough review and evaluation of grey literature and non-English documents on the topic, and included only a few grey literature references to provide context. While we acknowledge that reports, e.g. of the European Union, on strategies to respond to water insecurity, the threats related to climate change and homelessness, could have added valuable insights, a respective analysis was outside of the scope of this review.

The homeless populations covered by studies included in this review ranged from people experiencing homelessness sleeping rough, in shelters to staying in encampments. Besides, where someone experiencing homelessness stays is dynamic and changes over time. The various different forms and types of homelessness, the different life realities of people experiencing homelessness, and the different WASH-, climate-, and health-related challenges and needs that come with them, are not comparable. Yet still, providing insights into the combined challenges based on the limited literature available adds value to our understanding, informs practice and decision-making, and constitutes a foundation for health-promoting action.

The included papers did not evenly represent HICs (Table 3). In fact, only evidence from the United States, Canada, Australia, South Africa, France, Poland and Portugal was identified, which means that information from the majority of HICs globally was not included.

Limited evidence on solid waste management and health could be identified through our scoping review. This might uncover a limitation of our search strategy, that failed to capture respective literature.

The depth of information provided by included studies varied substantially, with very few papers reporting in great detail on aspects related to climate-resilient WASH among people experiencing homelessness in urban areas in HICs, while others only marginally touched upon the links (Table 4). Furthermore, evidence in publications included in this review was captured at different geographical and organizational scales, considered different disciplinary perspectives, and used different methodological approaches and definitions (Table 3). This imbalance and variation highlight the paucity of information related to the subject, and the added value of the grounded theory we developed based on our results.

Although the access to WASH services among people experiencing homelessness vary in space and time, no longitudinal studies were identified that compare WASH and health service provision at different times and seasons of the year. A comparison of access to services, and perceptions among people experiencing homelessness during different seasons, and during heatwaves, flooding, periods of extreme cold – and spatial analyses on comparing implications in different geographical settings, would have been useful in shedding light on this complex topic. A systematic integration of different perspectives from people experiencing homelessness, stratified by subpopulation (e.g. women, youths, people with limited mobility), their service providers and decision-makers through transdisciplinary research would have added value to better understand barriers and solutions to climate-resilient WASH in urban areas.

5. Conclusions and recommendations to improve climate-resilient and inclusive WASH

Although urban areas vary considerably in their extreme weather patterns, built environments, WASH infrastructure and homeless populations, and homeless services provided (Wandel et al., 2010), limiting the representativity of our findings, with extreme weather events increasing in frequency, severity and unpredictability, our results and our resulting framework offer an opportunity for climate-resilient and inclusive WASH planning and programming.

Decision-makers should create and adopt plans and policies for extreme weather events, the implementation of which shall be responsive to homeless individuals' specific drinking water, sanitation, hygiene, health and housing needs (Ho et al., 2007; Kidd et al., 2021). Climate change needs to be included in research and policy agendas for housing and homelessness, and the vulnerability and specific WASH and health needs of the homeless should be better incorporated in climate change adaptation and disaster planning (Gibson, 2019; Kidd et al., 2021a,b; Pendrey et al., 2014). Communication with those directly affected by extreme weather events, as well as those responding to them, is key (Marcus et al., 2020). The development of plans and policies shall be co-designed with impacted individuals and organizations, and involve people experiencing homelessness – visible and hidden –, service providers and decision-makers alike (English et al., 2022; Gibson, 2019; Kidd et al., 2021a,b; Klein and Riemer, 2011; Nicolay et al., 2016; Portillo et al., 2022; Zhang et al., 2018), to enhance communication with people experiencing homelessness before, during and after extreme weather events, and place the issue in an international framework, to support the effectiveness of interventions (Cusack et al., 2013; DeVuono-Powell, 2013; Gibson, 2019).

Local governments should prioritize extreme weather plans that designate a lead agency or organization, include clear responsibilities, warning systems based on weather data, education on preparedness and communication with the public. Such plans should identify populations at risks – such as people experiencing homelessness, train and employ outreach teams to serve them, document and evaluate information so to improve plans based on lessons learned. A stock of supplies – e.g. drinking water, tents, sunscreen, shelters with air conditioning and mobile medical care with intravenous fluids and ice packs – and climate-, health-, and WASH-related awareness raising and information material should always be ready for the case of extreme weather events (Every et al., 2021; Gibson, 2019; Kidd et al., 2021a,b; Pendrey et al., 2014).

To respond to water insecurity and resulting heat-related health issues during heatwaves, for example, measures and coping mechanisms include improved access to public water fountains (Kidd et al., 2021a,b), provision of water for all through bottled water or water purification devices to people experiencing homelessness through authorities and service providers (Nicolay et al., 2016). Likewise, people experiencing homelessness can respond themselves consuming drinking water whenever and wherever available to stave off the onset of dehydration (Every et al., 2021), acquiring drinking water through social network, exploiting hidden water sources (e.g. spigot), and borrowing money to buy water. For non-potable water needs, modifying water consumption has been recommended, i.e. reusing or cutting back on consumption to save water (DeMeyers et al., 2017; Wutich and Brewis, 2014).

To improve sanitation for people experiencing homelessness and reduce systematic challenges such as safety, privacy and accessibility (Leibler et al., 2017), recommended interventions include the installation of new, portable staffed restrooms where no public restrooms previously existed; staffing previously existing unstaffed public restrooms; and expanding service hours of public facilities from daytime-only to 24 h per day (Amato et al., 2022). DeVuono-Powell (2013) recommends the installation of durable infrastructures and facilities rather than installing temporary portable toilets. Unhoused people in Skid Row, Los Angeles, California, United States further recommend toilets to have sinks, provide adequate hygiene supplies and emergency buttons (Ares et al., 2017). Decentralized and localized sanitation interventions could be effective at reducing open defecation (Capone et al., 2018). Establishing high quality standards for public toilets, and monitoring their functionality, maintenance, accessibility, safety, privacy would be another effective measure. When building new toilets, or when conducting needs assessments, the UN standard of providing toilets within 50 m should be used, and that might require placing toilets in parks and parking lots. Successful initiatives in addressing limited access to sanitation and reducing open defecation include “At Your Service” kiosks with the space around public toilets transformed into “safe spaces” (Ares et al.,

2017) and the “Pit Stop Program” which provides free, public toilets, commonly staffed with attendants ensuring cleanliness, safety, and adequate stock with supplies, waste bins, dog waste bags, and needle disposal boxes. As part of this programme, existing toilets were converted to staffed facilities equipped with self-cleaning, and new portable self-cleaning toilets were created with gender-neutral units, stalls and sinks, and wheelchair accessible. The implementation of this project lead to a long-term reduction in the rate of reports of exposed faeces (Amato et al., 2022). An expansion of such interventions, with regular audits for quality, utilization, and user experience could improve sanitation services according to the specific needs of people experiencing homelessness (Amato et al., 2022).

To respond to hygiene insecurity and resulting risk of skin infections during periods of extreme cold, for example, measures include health education on (foot) hygiene, frequent self-examination for hygiene-related infections, regular showering, supplies of hygiene products, sanitizing public showers and follow up (Chen et al., 2014). Portable hygiene facilities and handwashing stations with access to clean water should be provided in areas where homeless individuals congregate (Ares et al., 2017; Kushel 2018).

To prepare for, adapt and respond to extreme weather conditions, may that be heatwaves, periods of extreme cold, heavy rain or flooding, good data is needed to enable the prediction of climate-vulnerable hotspots, early warning systems and extreme weather alerts, targeted to the general public and to the most vulnerable groups within a society to prevent or minimize the health effects, particularly considering that these are some of the most pressing concerns for homeless populations in the coming years (Ramin and Svoboda, 2009), and considering that the prevalence of homelessness globally may be increasing due to the climate and weather vulnerabilities (Anderson et al., 2021; Kidd et al., 2021a,b). More research is needed to better understand the climate, health, WASH and homelessness nexus, and more funding is required to determine risks and strategies for protection and coping. Increased monitoring and a prompt response from public health authorities to ensure effective and timely implementation of evidence-based, low-cost response strategies through community outreach and climate-resilient infrastructure could be part of protecting people experiencing homelessness during extreme weather events (English et al., 2022).

This requires a careful review of existing and planned WASH and health services to assess whether they will be sufficient in preventing future vulnerabilities to extreme weather event (Wandel et al., 2010; Zhang et al., 2019). Advocates and organizations that serve the homeless may need to educate and advocate on their behalf to help ensure they are not denied, for instance due to stigma, access to needed resources during or after extreme weather events (Gibson, 2019). The provision of drinking water, toilet and hygiene infrastructure – even if they adhere to the HRTWS – will not be enough (Frye et al., 2019). Universal access can only be achieved when universal affordable housing exists (Capone et al., 2020). Without housing, it is likely impossible to have consistent access to WASH when and where they are needed (Feinstein and Daies, 2019; Ares et al., 2017). Thus, affordable and adequate housing is still the best option to provide a potentially cost-effective, sustainable solution, which also improves health, life expectancy, and the dignity of people experiencing homelessness (Frye et al., 2019). To really improve climate-resilient and inclusive WASH for people experiencing homelessness in urban areas in HICs, climate change needs to be included in research agendas for housing and homelessness, and the vulnerability and specific needs related to WASH of people experiencing homelessness need to be better incorporated in climate change adaptation and disaster planning (Pendrey et al., 2014). To achieve this, state, regional, and local governments must prioritize finding resources that support related research and interventions (DeVuono-Powell, 2013; Feinstein and Daies, 2019; Portillo et al., 2022).

Future research in the context of climate-resilient and inclusive WASH for people experiencing homelessness in urban areas in HICs is needed to better understand the situation, the challenges and lived

experiences of the population affected, so to extend the theory we grounded based on scientific literature (Fig. 2). More depth investigations on differences between subgroups (e.g. women, youths, sexual minorities, formerly incarcerated people and disabled persons) (Badiaga et al., 2008; DeVuono-Powell, 2013; Flanigan and Welsh, 2020; Ho et al., 2007; Moffa et al., 2019) and based on different features of people experiencing homelessness (age, mental health, substance use, type of homelessness), and different complex contexts and life realities are needed that account for environmental factors, different urban contexts, social and economic environments, programs and policies targeting people experiencing homelessness that affect WASH and health service access (Gibson, 2019; Winkleby 1990). More research is needed also on the implications of extreme cold, heavy rain and flooding on WASH and health among people experiencing homelessness in urban areas. Transdisciplinary, community-based research approaches and collaboration with people experiencing homelessness as key informants (Moffa et al., 2019), practitioners, including homeless care providers, social workers, healthcare providers, water and sanitation providers, urban planners and related decision-makers are required to address the multifaceted and complex challenges that people experiencing homelessness are facing in the context of climate-resilient and inclusive WASH (Portillo et al., 2022), identify areas in which improvements and interventions are needed, design technologies and services that meet the needs of this unique situation (Verbyla et al., 2021), and ultimately achieve social change (Portillo et al., 2022).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijheh.2023.114285>.

References

- Aldridge, R.W., Story, A., Hwang, S.W., Nordentoft, M., Luchenski, S.A., Hartwell, G., Tweed, E.J., Lewer, D., Katikireddi, S.V., Hayward, A.C., 2018. Morbidity and mortality in homeless individuals, prisoners, sex workers, and individuals with substance use disorders in high-income countries: a systematic review and meta-analysis. *Lancet* 391 (10117), 241–250. [https://doi.org/10.1016/S0140-6736\(17\)31869-X](https://doi.org/10.1016/S0140-6736(17)31869-X).
- Allaria, C., Loubiere, S., Mosnier, E., Monfardini, E., Auquier, P., Tinland, A., 2021. “Locked down outside”: perception of hazard and health resources in COVID-19 epidemic context among homeless people. *SSM – Popul. Health* 15, 100829. <https://doi.org/10.1016/j.ssmph.2021.100829>.
- Amato, H.K., Martin, D., Hoover, C.M., Graham, J.P., 2022. Somewhere to go: assessing the impact of public restroom interventions on reports of open defecation in San Francisco, California from 2014 to 2020. *BMC Publ. Health* 22, 1673. <https://doi.org/10.1186/s12889-022-13904-4>.
- Anderson, M.-C., Hazel, A., Perkins, J.M., Almquist, Z.W., 2021. The ecology of unsheltered homelessness: environmental and social-network predictors of well-being among an unsheltered homeless population. *Int. J. Environ. Res. Publ. Health* 8 (18), 7328. <https://doi.org/10.3390/ijerph18147328>, 14.

- Anthonj, C., Setty, K.S., Ezbakhe, F., Manga, M., Hoese, C., 2020b. A systematic review of water, sanitation, hygiene and environmental health among Roma communities in Europe: situation analysis, cultural context, and obstacles to improvement. *Int. J. Hyg. Environ. Health* 226 (113506). <https://doi.org/10.1016/j.ijheh.2020.113506>.
- Anthonj, C., Tracy, J.W., Fleming, L., Shields, K.F., Tikoisuvu, W.M., Kelly, E.R., Thakkar, M.B., Cronk, R.D., Overmars, M., Bartram, J., 2020a. Geographical inequalities in drinking water in the Solomon Islands. *Sci. Total Environ.* 712, 135241. <https://doi.org/10.1016/j.scitotenv.2019.135241>.
- Australian Census of Population and Housing, 2021. Available at: <https://www.abs.gov.au/statistics/people/housing/estimating-homelessness-census/latest-release>. (Accessed 28 August 2023).
- Ares, E., Bacalao, P., Campos, S., Dean, E., Dickenson, I., Fauvre, A., Grode, T., Johnson, S., Jones, G., Kassenbrock, R., Key, K.M., Kozowy, J., Kuykendall, E., Laurent, A., Mbella, L., McNenny, K., Porter, C., Robison, J., Schultz, C., Shaw, S., Short, S., Spiegel, G., Unton, M., Waldman, D., 2017. No place to go: an audit of public toilets in skid row. *Inner City Law Center*. Available at: <https://www.innercitylaw.org/wp-content/uploads/2017/07/No-Place-To-Go-final.pdf>. (Accessed 4 July 2023).
- Arkey, H., O'Malley, L., 2005. Scoping studies: towards a methodological framework. *Int. J. Soc. Res. Methodol.* 8 (1) <https://doi.org/10.1080/1364557032000119616>.
- Badiaga, S., Raoult, D., Brouqui, P., 2008. Preventing and controlling emerging and re-emerging transmissible diseases in the homeless. *Emerg. Infect. Dis.* 14 (9), 1353–1359. https://wwwnc.cdc.gov/eid/article/14/9/08-0204_article.
- Baldwin, D., 1998. The subsistence adaptation of homeless mentally ill women. *Hum. Organ.* 57 (2), 190–199. <https://www.jstor.org/stable/44126906>.
- Ballard, A.M., Cooper, H.L.F., Young, A.M., Caruso, B.A., 2022. 'You feel how you look': exploring the impacts of unmet water, sanitation, hygiene needs among rural people experiencing homelessness and their intersection with drug use. *PLOS Water* 1 (5), e0000019. <https://doi.org/10.1371/journal.pwat.0000019>.
- Bartram, J., Cairncross, S., 2010. Hygiene, sanitation, and water: forgotten foundations of health. *PLoS Med.* 7 (11), e1000367. <https://doi.org/10.1371/journal.pmed.1000367>.
- Bezgrebelna, M., McKenzie, K., Wells, S., Ravindran, A., Kral, M., Christensen, J., Stergiopoulos, V., Gaetz, S., Kidd, S.A., 2021. Climate change, weather, housing precarity, and homelessness: a systematic review of reviews. *Int. J. Environ. Res. Publ. Health* 18 (11), 5812. <https://doi.org/10.3390/ijerph18115812>.
- Boden, L., Wolski, A., Rubin, A.S., Pfaltzgraff Oliveira, L., Tyminski, Q.P., 2021. Exploring the barriers and facilitators to menstrual hygiene management for women experiencing homelessness. *J. Occup. Sci.* 30 (2) <https://doi.org/10.1080/14427591.2021.1944897>.
- Bonds, E., Martin, L., 2016. Treating people like pollution: homelessness and environmental injustice. *Environ. Justice* 9 (5), 137–141. <https://doi.org/10.1089/env.2016.0021>.
- Bradley, D., 1974. Water supplies: the consequences of change. In: Elliott, K., Knight, J. (Eds.), *Human Rights in Health*. Ciba Foundation Symposium 23. Associated Publishers, Amsterdam, London, New York, pp. 81–98.
- Brown, J., Acey, C.S., Anthonj, C., Barrington, D.J., Beal, C.D., Capone, D., Cumming, O., Pullen Fedinick, K., MacDonald Gibson, J., Hicks, B., Kozubik, M., Lakatosova, N., Linden, K.G., Love, N.G., Mattos, K.J., Murphy, H.M., Winkler, I.T., 2023. The effects of racism, social exclusion, and discrimination on achieving universal safe water and sanitation in high-income countries. *Lancet Global Health* 11 (4), E606–E614. [https://doi.org/10.1016/S2214-109X\(23\)00006-2](https://doi.org/10.1016/S2214-109X(23)00006-2).
- Burton, B., Pollio, D.E., North, C.S., 2018. A longitudinal study of housing status and crime in a homeless population. *Ann. Clin. Psychiatr.* 30 (4), 280–288.
- Capone, D., Cumming, O., Nichols, D., Brown, J., 2020. Water and sanitation in urban America, 2017–2019. *Am. J. Publ. Health* 110 (10), 1567–1572. <https://doi.org/10.2105/AJPH.2020.305833>.
- Capone, D., Ferguson, A., Gribble, M.O., Brown, J., 2018. Open defecation sites, unmet sanitation needs, and potential sanitary risks in Atlanta, Georgia, 2017–2018. *Am. J. Publ. Health* 108 (9), 1238–1240. <https://doi.org/10.2105/AJPH.2018.304531>.
- Chen, B., Mitchel, A., Tran, D., 2014. "Step up for foot care". Addressing podiatric care needs in a sample homeless population. *J. Am. Podiatr. Med. Assoc.* 104 (3), 269–276.
- Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., Lee, M., Levy, C., Maslin, M., McCoy, D., McGuire, B., Montgomery, H., Napier, D., Pagel, C., Patel, J., Puppim de Oliveira, J.A., Redclift, N., Rees, H., Rogger, D., Scott, J., Stephenson, J., Twigg, J., Wolff, J., Patterson, C., 2009. Managing the health effects of climate change: lancet and university college London institute for global health commission. *Lancet* 373, 1693–1733. [https://doi.org/10.1016/S0140-6736\(09\)60935-1](https://doi.org/10.1016/S0140-6736(09)60935-1).
- Cusack, L., van Loon, A., Kralik, D., Arbon, P., Gilbert, S., 2013. Extreme weather-related health needs of people who are homeless. *Aust. J. Prim. Health* 19, 250–255. <https://doi.org/10.1071/PY12048>.
- Cutler, D., Miller, G., 2005. The role of public health improvements in health advances: the twentieth-United States. *Demography* 42 (1), 1–22. <https://doi.org/10.1353/dem.2005.0002>.
- Debska, K., Mosowska, M., 2021. The stranded cinderella and the wandering rascal. Two narratives of female housing exclusion. *Emot. Space Soc.* 39, 100793. <https://doi.org/10.1016/j.emospa.2021.100793>.
- de Gómez, W., 2010. Vulnerability to Climate Related Events: A Case Study of the Homeless Population in Waterloo Region. MSc thesis. University of Waterloo, p. 171.
- DeMeyers, C., Warpinski, C., Wutich, A., 2017. Urban water insecurity: a case study of homelessness in Phoenix, Arizona. *Environ. Justice* 10 (3), 72–80. <https://doi.org/10.1089/env.2016.0043>.
- DeVuo-Powell, S., 2013. Homeless encampments in Contra Costa county: a report for the Contra Costa county flood control and water conservation district. Martinez, CA: Contra Costa county. Available at: www.contracosta.ca.gov/Document Center/View/27388. (Accessed 1 August 2023).
- Donovan, E., Unice, K., Roberts, J.D., Harris, M., Finley, B., 2008. Risk of gastrointestinal disease associated with exposure to pathogens in the water of the lower Passaic River. *Appl. Environ. Microbiol.* 74 (4), 994–1003. <https://doi.org/10.1128/AEM.00601-07>.
- English, T., Larkin, M., Vasquez Hernandez, A., Hutton, J., Currie, J., 2022. Heat illness requiring emergency care for people experiencing homelessness. A case study series. *Int. J. Environ. Res. Publ. Health* 19, 16565. <https://doi.org/10.3390/ijerph192416565>.
- European Parliament, 2020. Available at: <https://www.europarl.europa.eu/news/en/headlines/society/20201119STO92006/how-parliament-wants-to-end-homelessness-in-the-eu#:~:text=Housing%20is%20a%20fundamental%20human,to%20hygiene%20and%20health%20care>. (Accessed 28 August 2023).
- Every, D., McLennan, J., Osborn, E., Cook, C., 2021. Experiences of heat stress while homeless on hot summer days in Adelaide. *Aust. J. Emerg. Manag.* 36 (4), 55–61. <https://doi.org/10.47389/36.4.55>.
- Every, D., Richardson, R., 2017. Building the Disaster Resilience of the Homeless Community. QUniversity & Red Cross in Collaboration with VCOSS, NCCARF and ShelterSA, p. 67pp.
- Fazel, S., Geddes, J.R., Kushel, M., 2014. The health of homeless people in high-income countries: descriptive epidemiology, health consequences, clinical and policy recommendations. *Lancet* 384 (9953), 1529–1540.
- Feinstein, L., Daies, G., 2019. Plumbing the depths: californians without toilets and running water. Pacific Institute. Available at: <https://pacinst.org/wpcontent/uploads/2019/07/plumbing-the-depths.pdf>. (Accessed 29 June 2023).
- Felner, J.K., Kieu, T., Stieber, A., Call, H., Kirkland, D., Farr, A., Calzo, J.P., 2020. "It's just a band-aid on something no one really wants to see or acknowledge": a photovoice study with transitional aged youth experiencing homelessness to examine the roots of San Diego's 2016–2018 hepatitis A outbreak. *Int. J. Environ. Res. Publ. Health* 17, 4721. <https://doi.org/10.3390/ijerph17134721>.
- Flanigan, S., Welsh, M., 2020. Unmet needs of individuals experiencing homelessness near San Diego waterways: the roles of displacement and overburdened service systems. *J. Health Hum. Serv. Adm.* 43 (2), 105–130. <https://doi.org/10.137808/jhhsa.43.2.3>.
- Fleming, L., Anthonj, C., Thakkar, M.B., Tikoisuvu, W.M., Cronk, R., Kelly, E., Shields, K.F., Manga, M., Howard, G., Overmars, M., Bartram, J., 2019. Urban and rural sanitation and hygiene in the Solomon Islands: resilient to extreme weather events? *Sci. Total Environ.* 683, 331–340. <https://doi.org/10.1016/j.scitotenv.2019.05.253>.
- Flores-Baquero, O., Jiménez Fdez de Palencia, A., Pérez Foguet, A., 2015. Reporting progress on the human right to water and sanitation through JMP and GLAAS. *J. Water, Sanit. Hyg. Dev.* 5, 310–321. <https://doi.org/10.2166/washdev.2015.151>.
- Freeman, M.C., Garn, J.V., Sclar, G.D., Boisson, S., Medlicott, K., Alexander, K.T., Penakalapati, G., Anderson, D., Mahtani, A.G., Grimes, J.E.T., Rehfuess, E.A., Clasen, T.F., 2017. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *Int. J. Hyg. Environ. Health* 220 (6), 928–949. <https://doi.org/10.1016/j.ijheh.2017.05.007>.
- Frye, E.A., Capone, D., Evans, D.P., 2019. Open defecation in the United States: perspectives from the streets. *Environ. Justice* 12 (5), 226–230. <https://doi.org/10.1089/env.2018.0030>.
- Gaetz, S., Dej, E., Richter, T., Redman, M., 2016. *The State of Homelessness in Canada 2016*. Canadian Observatory on Homelessness Press, Toronto.
- Gibson, A., 2019. Climate change for individuals experiencing homelessness: recommendations for improving policy, research, and services. *Environ. Justice* 12 (4), 159–163. <https://doi.org/10.1089/env.2018.0032>.
- Giné-Garriga, R., Flores-Baquero, O., Jiménez-Fdez de Palencia, A., Pérez-Foguet, A., 2017. Monitoring sanitation and hygiene in the 2030 Agenda for Sustainable Development: a review through the lens of human rights. *Sci. Total Environ.* 580, 1108–1119. <https://doi.org/10.1016/j.scitotenv.2016.12.066>.
- Harris, M., Scott, J., Hope, V., Wright, T., McGowan, C., Ciccarone, D., 2020. Navigating environmental constraints to injection preparation: the use of saliva and other alternatives to sterile water among unstably housed PWID in London. *Harm Reduct. J.* 17 (1), 1–11.
- Ho, P.-S., Kroll, T., Kehn, M., Anderson, P., Pearson, K.M., 2007. Health and housing among low-income adults with physical disabilities. *J. Health Care Poor Underserved* 18, 902–915. <https://doi.org/10.1353/hpu.2007.0098>.
- Howard, G., Calow, R., MacDonald, A., Bartram, J., 2016. Climate change and water and sanitation: likely impacts and emerging trends for action. *Annu. Rev. Environ. Resour.* 41, 253–276. <https://doi.org/10.1146/annurev-environ-110615-085856>.
- Hrycko, A., Mateu-Gelabert, P., Ciervo, C., Linn-Walton, R., Eckhardt, B., 2022. Severe bacterial infections in people who inject drugs: the role of injection-related tissue damage. *Harm Reduct. J.* 19 (41) <https://doi.org/10.1186/s12954-022-00624-6>.
- IPCC, 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.
- Kerman, N., Wang, R., Aubry, T., Distasio, J., Gaetz, S., Hwang, S.W., Latimer, E., O'Grady, B., Schwan, K., Somers, J.M., Stergiopoulos, W., Kidd, S.A., 2022. Shelter bans among people experiencing homelessness: an exploratory study of predictors in two large Canadian datasets. *J. Urban Health* 99, 842–854. <https://doi.org/10.1007/s11524-022-00680-0>.
- Kidd, S.A., Hajat, S., Bezgrebelna, M., McKenzie, K., on behalf of the Climate-Homelessness Working Group, 2021a. The climate change-homelessness nexus. *Lancet* 397, 1693–1694. [https://doi.org/10.1016/S0140-6736\(21\)00834-5](https://doi.org/10.1016/S0140-6736(21)00834-5).
- Kidd, S.A., Greco, S., McKenzie, K., 2021b. Global climate implications for homelessness: a scoping review. *J. Urban Health* 98, 385–393. <https://doi.org/10.1007/s11524-020-0483-1>.

- Klein, K., Riemer, M., 2011. Experiences of environmental justice and injustice in communities of people experiencing homelessness. *Ecopsychology* 3 (3), 195–204. <https://doi.org/10.1089/eco.2011.0039>.
- Krennerich, M., 2021. Wahlrecht von wohnungslosen Menschen. Rechtliche, organisatorische und politische Bedingungen der Wahlrechtsnutzung durch wohnungslose Menschen. Deutsches Institut für Menschenrechte, Berlin.
- Kushel, M., 2018. Hepatitis A outbreak in California – addressing the root cause. *N. Engl. J. Med.* 378 (3), 211–213. <https://doi.org/10.1056/nejmp1714134>.
- Kyper, E.S., Douglas, M.J., Lees, L.S., 2022. Managing homeless patient risk in a U.S. Healthcare system. *WIT Trans. Built Environ.* 214, 51–55. <https://doi.org/10.2495/SSR220041>.
- Leibler, J.H., Nguyen, D., León, C., Gaeta, J., Perez, D., 2017. Personal hygiene practices among urban homeless. *Int. J. Environ. Res. Publ. Health* 14 (8). <https://doi.org/10.3390/ijerph14080928> pii:E928.
- Leibler, J.H., Zakhour, C.M., Gadhoke, P., Gaeta, J.M., 2016. Zoonotic and vector-borne infections among urban homeless and marginalized people in the United States and Europe, 1990–2014. *Vector Borne Zoonotic Dis.* 16 (7), 435–444. <https://doi.org/10.1089/vbz.2015.1863>.
- Levac, D., Colquhoun, H., O'Brien, K.K., 2010. Scoping studies: advancing the methodology. *Implement. Sci.* 69 (5) <https://doi.org/10.1186/1748-5908-5-69>.
- Lupien, S., Liu, H., Lobato, A., Myerson, D., Schwartz, B., Polsky, C., 2018. Basic and Urgent: Realizing the Human Right to Sanitation for Californians Experiencing Homelessness. Environmental Law Clinic, University of California, Berkeley Law. https://www.law.berkeley.edu/wp-content/uploads/2018/08/FINAL_EJCW.ELC_Basic_UrgentReportonAccessToWaterandSanitationbyHomelessCalifornians.8.8.18.docx.pdf. (Accessed 24 June 2023).
- Mara, D., Lane, J., Scott, B., Trouba, D., 2010. Sanitation and health. *PLoS Med.* 7 (11), e1000363.
- Marcus, T.S., Heese, J., Scheibe, A., Shelly, S., Lalla, S.X., Hugo, J.F., 2020. Harm reduction in an emergency response to homelessness during South Africa's COVID-19 lockdown. *Harm Reduct. J.* 17 (60) <https://doi.org/10.1186/s12954-020-00404-0>.
- Moffa, M., Cronk, R., Fejfar, D., Dancausse, S., Acosta Padilla, L., Bartram, J., 2019. A systematic scoping review of environmental health conditions and hygiene behaviors in homeless shelters. *Int. J. Hyg Environ. Health* 222 (3), 335–346. <https://doi.org/10.1016/j.ijheh.2018.12.004>.
- Molotch, H., Noren, L. (Eds.), 2010. Toilet: Public Restrooms and the Politics of Sharing. NYU Press.
- Moreira Marques, T., Oliveira Nascimento, P., Almeida, A., Tosatto, V., 2020. Weil's disease in a young homeless man living in Lisbon. *BMJ Case Rep.* 13, e233543 <https://doi.org/10.1136/bcr-2019-233543>.
- Nickasch, B., Marnocha, S.K., 2009. Healthcare experiences of the homeless. *J. Am. Acad. Nurse Pract.* 21, 39–46. <https://doi.org/10.1111/j.1745-7599.2008.00371.x>.
- Nicolay, M., Brown, L.M., Johns, R., Ialynytchev, A., 2016. A study of heat related illness preparedness in homeless veterans. *Int. J. Disaster Risk Reduc.* 18, 72–74. <https://doi.org/10.1016/j.ijdrr.2016.05.009>.
- O'Sullivan, E., 2022. Key Elements in Homelessness Strategies to End Homelessness by 2030: A Discussion Paper. European Platform on Combatting Homelessness. Publications Office of the European Union, Luxembourg.
- Palta, M., du Bray, M.V., Stotts, R., Wolf, A., Wutich, A., 2016. Ecosystem services and disservices for a vulnerable population: findings from urban waterways and wetlands in an American desert city. *Hum. Ecol.* 44, 463–478. <https://doi.org/10.1007/s10745-016-9843-8>.
- Pendrey, C.G.A., Carey, M., Stanley, J., 2014. Impacts of extreme weather on the health and well-being of people who are homeless. *Aust. J. Prim. Health* 20, 2–3. <https://doi.org/10.1071/PY131>.
- Pinongcos, F., Mladenov, N., Calderon, J., Verbyla, M.E., Kinoshita, A.M., Gersberg, R., Batikian, C.M., 2022. Chemical and microbial markers for discriminating sanitary sewer contamination in coastal, urban streams. *ACS EST Water* 2, 1747–1759. <https://doi.org/10.1021/acsestwater.2c00265>.
- Portillo, L.J.A., Kayser, G., Ko, C., Vasquez, A., Gonzalez, J., Avelar, D.J., Alvarenga, N., Franklin, M., Chiang, Y.-Y., 2022. Water, sanitation, and hygiene (WaSH) insecurity in unhoused communities of Los Angeles, California. *Int. J. Equity Health* 22 (108). <https://doi.org/10.1186/s12939-023-01920-8>.
- Ramin, B., Svoboda, T., 2009. Health of the homeless and climate change. *J. Urban Health: Bull. N. Y. Acad. Med.* 86, 654–663. <https://doi.org/10.1007/s11524-009-9354-7>.
- Ramsden, E., 2020. Realizing healthful housing: devices for data travel in public health and urban redevelopment in the twentieth century United States. In: Leonelli, S., Tempini, N. (Eds.), *Data Journeys in the Sciences*. Springer International Publishing, pp. 329–349.
- Romaszko, J., Cymes, I., Draganska, E., Kutcha, R., Glinska-Lewczuk, K., 2017. Mortality among the homeless: causes and meteorological relationships. *PLoS One* 12 (12), e0189938. <https://doi.org/10.1371/journal.pone.0189938>.
- Rosengard, C., Chambers, D.B., Tulskey, J.P., Long, H.L., Chesney, M., 2001. Value on health, health concerns and practices of women who are homeless. *Women Health* 34, 29.
- Rosenthal, D.M., Ucci, M., Heys, M., Schoenthaler, A., Lakhanpaul, M., Hayward, A., Lewis, C., 2022. A citizen science approach to identifying indoor environmental barriers to optimal health for under 5s experiencing homelessness in temporary accommodation. *Int. J. Environ. Res. Publ. Health* 19 (3976). <https://doi.org/10.3390/ijerph19073976>.
- Roy, L., Crocker, A.G., Nicholls, T.L., Latimer, E.A., Reyes Ayllon, A., 2014. Criminal behavior and victimization among homeless individuals with severe mental illness: a systematic review. *Psychiatr. Serv.* 65 (6), 739–750. <https://doi.org/10.1176/appi.ps.201200515>.
- Sanchez, C., 2011. Tricks of the Shade: Heat Related Coping Strategies of Urban Homeless Persons in Phoenix, Arizona. (unpublished Masters dissertation) Arizona State University, Tempe, Arizona, USA. At: https://repository.asu.edu/attachments/56507/content/Sanchez_asu_0010N_10545.pdf.
- Steele, J., Griffith, J., Noble, R., Schiff, K., 2017. Tracking Human Fecal Sources in an Urban Watershed during Wet Weather. Technical Report 1002. Southern California Coastal Water Research Project, Costa Mesa, CA.
- United Nations, 2015a. Human Right to Safe Drinking Water and Sanitation. United Nations, Geneva.
- United Nations, 2015b. Transforming Our World: the 2030 Agenda for Sustainable Development. United Nations, Geneva.
- United Nations, 2010. General Assembly Resolution 64/292, the Human Right to Water and Sanitation, A/RES/64/292. United Nations General Assembly, Geneva, Switzerland.
- United Nations, 2014. Realizing the Human Rights to Water and Sanitation: A Handbook by the UN Special Rapporteur Catarina de Albuquerque. United Nations, Lisbon, Portugal.
- United States Department of Housing and Urban Development Office of Community Planning and Development, 2022. The 2022 annual homelessness assessment report (AHAR) to congress. Available at: <https://www.huduser.gov/portal/sites/default/files/pdf/2022-AHAR-Part-1.pdf>. (Accessed 28 August 2023).
- Verbyla, M.E., Calderon, J.S., Flanigan, S., Garcia, M., Gersberg, R., Kinoshita, A.M., Mladenov, N., Pinongcos, F., Welsh, M., 2021. An assessment of ambient water quality and challenges with access to water and sanitation services for individuals experiencing homelessness in riverine encampments. *Environ. Eng. Sci.* 38, 389–401. <https://doi.org/10.1089/ees.2020.0319>.
- Walters, V., Gaillard, J.C., 2014. Disaster risk at the margins: homelessness, vulnerability and hazards. *Habitat Int.* 44, 211–219. <https://doi.org/10.1016/j.habitatint.2014.06.006>.
- Wandel, J., Riemer, M., de Gomez, W., Klein, K., de Schutter, J., Randall, L., Morrisson, M., Poirier, S., Singleton, C., 2010. Homelessness and Global Climate Change: Are We Ready? A Report from the Study on the Vulnerability to Global Climate Change of People Experiencing Homelessness in Waterloo Region. Wilfrid Laurier University, Waterloo, Canada.
- Wescoat Jr., J.L., Headington, L., Theobald, R., 2006. Water and poverty in the United States. *Geoforum* 38, 801–814. <https://doi.org/10.1016/j.geoforum.2006.08.007>.
- WHO/UNICEF JMP Household WASH Data, 2019. United Nations Children's Fund and World Health Organization. <https://washdata.org/data/household#!/table?geo=country&geo1=USA>. (Accessed 24 June 2021).
- World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply Sanitation and Hygiene, 2019. Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017. Special Focus on Inequalities. New York, NY.
- Winkleby, 1990. Comparison of risk factors for ill health in a sample of homeless and non-homeless poor. *Publ. Health Rep.* 105 (4), 404–410.
- Zhang, P., Bassil, K., Gower, S., Katic, M., Kiss, A., Gogosis, E., Hwang, S.W., 2018. Cold-related injuries in a cohort of homeless adults. *J. Soc. Distress Homeless.* <https://doi.org/10.1080/10530789.2018.1523103>.
- Zhang, P., Wiens, K., Wang, R., Luong, L., Ansara, D., Gower, S., Bassil, K., Hwang, S.W., 2019. Cold weather conditions and risk of hypothermia among people experiencing homelessness: implications for prevention strategies. *Int. J. Environ. Res. Publ. Health* 16, 3259. <https://doi.org/10.3390/ijerph16183259>.