



Lived sanitation experiences in informal and formal settlements in Nairobi, Kenya: A comparative study through the lens of the Human Right to Sanitation

Julia Foellmer^{a,*}, Dennis Musyoka^b, Sarah Lebu^c, Dancan Owaga^b, Musa Manga^{c,d}, Paula Janeka^a, Caroline Kabaria^b, Carmen Anthonj^a

^a Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, the Netherlands

^b African Population and Health Research Center, Nairobi, Kenya

^c Department of Environmental Sciences and Engineering, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, United States

^d Department of Construction Economics and Management, College of Engineering, Design, Art and Technology, Makerere University, Kampala, Uganda

ARTICLE INFO

Handling Editor: Professor Jamie Pearce

ABSTRACT

Urban sanitation is essential for health and well-being, yet provision remains deeply unequal, particularly in informal settlements. This study compares lived sanitation experiences across Nairobi's informal and formal settlements and examines how water insecurity – too much, too little, too dirty water – intersects with sanitation. We combined eight focus group discussions (n = 65 participants) with household surveys (n = 545) to analyse disparities across Human Right to Sanitation (HRTS) normative content dimensions of availability, accessibility, quality, safety, affordability, and acceptability. Nearly all surveyed households in formal settlements have private, sewer facilities, whereas in informal settlements, private toilets are rare, often poorly constructed, shared, and unsafely managed. Low incomes, insecure land tenure, and user fees constrain infrastructure investment and maintenance, further restricting HRTS realisation. Sanitation systems in informal settlements are highly vulnerable to water insecurity, which can compromise waste containment and hygiene, with potential implications for exposure to waterborne diseases. In formal settlements, sewer systems limit disruptions, but water insecurity can compromise sanitation functionality and maintenance, while excess water can trigger sewer overflows and short-term service disruptions. HRTS realisation requires attention to all normative dimensions, integrating resilient infrastructure, safe faecal waste management, participatory governance, and community involvement, with attention to vulnerable groups, including women, children, and low-income households. Climate-resilient, systems-oriented approaches are essential to prevent faecal contamination, maintain service continuity, and support equitable health outcomes. By highlighting interactions between sanitation and water insecurity, this study provides actionable insights for designing urban sanitation systems that safeguard human rights, health, and dignity in rapidly urbanising cities.

1. Introduction

Access to adequate sanitation remains a global challenge and uneven across urban populations. Two out of five people worldwide do not have access to safely managed sanitation (UNICEF & WHO, 2025). In informal settlements, sanitation provision is shaped by multiple interrelated challenges (Lebu et al., 2024a; Sprouse et al., 2024). Physical constraints include limited space for facilities, unplanned layouts that complicate sewer construction, steep or flood-prone terrain, and narrow or unpaved

access, all of which hinder the construction, emptying, and treatment of human waste. The situation is worsened by the insufficient number of facilities, poor maintenance, and limited access to clean water (Chumo et al., 2023; Lebu et al., 2024a). Financial barriers further restrict service delivery, as residents' often lack the capacity or willingness to pay for sanitation, while high operational and maintenance costs, particularly in water-insecure areas, and shortages of skilled technicians impede maintenance (Chumo et al., 2023). Climate change is a cross-cutting challenge for water and sanitation services, exacerbating

* Corresponding author. Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Hallenweg 8, 7522 NH, Enschede the Netherlands.
E-mail address: j.foellmer@utwente.nl (J. Foellmer).

<https://doi.org/10.1016/j.socscimed.2026.119779>

Received 9 March 2026; Received in revised form 17 August 2026; Accepted 25 August 2026

Available online 26 August 2026

0277-9536/© 2026 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

existing challenges through flood-related infrastructure damage and declining water availability (Howard et al., 2016).

Legal and systemic barriers, such as insecure or non-existent tenancy agreements, and lack of formal recognition discourage investment in improved facilities and long-term sanitation solutions (Chumo et al., 2023; Lebu et al., 2024a; Sprouse et al., 2024). These barriers are rooted in broader processes of political exclusion in urban governance, through which informal settlements are marginalised in planning, investment, and service provision (McFarlane, 2023). This aggravates uneven sanitation infrastructure provision and unequal exposure to environmental health risks across urban settlements and populations, shaped by differences in sanitation access, use, and responsibilities associated with gender, age, and socioeconomic position (Chumo et al., 2023; Okurut et al., 2015). These inequalities contribute to broader urban health inequities in rapidly growing cities, where health outcomes are shaped by unequal access to the material conditions that sustain health and by the political processes that determine whose voices are heard and whose needs are prioritised in urban development (Corburn, 2017).

In Nairobi, where over half the population lives in informal settlements, these structural factors have contributed to widespread reliance on unimproved, shared toilets (Tomoi et al., 2025) with inadequate faecal sludge management, contributing to faecal contamination and public health risks (Sprouse et al., 2024). Open defecation remains common, further polluting drinking water sources and spreading disease. Whereas shared sanitation can improve access and reduce open defecation when well-designed and maintained (Lebu et al., 2024a; Sprouse et al., 2025), poorly managed or unhygienic facilities can generate dissatisfaction, conflict, psychological stress, and renewed reliance on unsafe practices (Tidwell et al., 2021). Despite growing attention to sanitation in informal settlements (Chumo et al., 2023; Sprouse et al., 2024), important gaps remain in understanding how sanitation provision and lived experiences differ across informal and formal urban settlements (Marphatia et al., 2025; Tidwell et al., 2021).

Addressing these challenges requires more than technical solutions. Sanitation services must be aligned with local needs and context to ensure safe, equitable, and dignified sanitation for all (Okurut et al., 2015). These principles of universality, equity, and attention to vulnerable groups, including women and girls, are reflected in Sustainable Development Goal (SDG) 6, which aims to achieve universal “access to adequate and equitable sanitation and hygiene for all and end open defecation” (United Nations, 2015). The Human Right to Water and Sanitation articulates these principles through the normative criteria of availability, accessibility, affordability, acceptability, and quality and safety (United Nations General Assembly, 2009, 2010b).

Applying the Human Right to Sanitation (HRTS) framework, this study examines lived sanitation experiences in informal and formal settlements in Nairobi through the normative criteria. It also explores how water insecurity, including too much, too little, or too dirty water, shapes lived sanitation experiences. Adopting a qualitative-led design, our focus group discussions reveal diverse lived experiences across settlements (with participants varying in age and gender), while a household survey provides contextualised descriptive indicators. Unlike most studies focusing exclusively on informal settlements, a key contribution is the application of HRTS normative content across settlement types, generating holistic, context-specific insights to inform more equitable urban planning and policy.

The following research questions were addressed.

1. To what extent is the HRTS realised in informal and formal settlements in Nairobi, Kenya?
2. How does water insecurity interact with sanitation conditions and affect the realisation of the HRTS?
3. How can sanitation be improved in Nairobi's informal settlements?

2. Methodology

2.1. Study sites: informal versus formal settlements in Nairobi, Kenya

This study was conducted in Nairobi, Kenya, across Jericho Lumumba and Harambee estates in Harambee ward, Makadara Sub-County, and three villages (Grogan A, Korogocho B, Kisumu Ndogo) in Korogocho ward, Ruaraka Sub-County (Fig. 1).

Jericho and Harambee estates are spatially planned by the Nairobi City County Government, predominantly middle-income neighbourhoods, characterised by single-storey dwellings with a few multistorey housing units, well-developed road networks, and greater access to quality services than in informal settlements (Ochako et al., 2016). Households have access to piped water and are connected to the sewer system (Foellmer et al., 2025).

In contrast, Korogocho is one of the most densely populated areas in Nairobi, lacks spatial planning, and is characterised by informal housing, limited infrastructure (Beguy et al., 2015), and chronic poverty (Wamukoya et al., 2020). Most residents rely on pit latrines, often shared among multiple households (Fig. 1) (Tomoi et al., 2025). Manual pit emptying is common, yet, lacks formal recognition or monitoring from local authorities (Chumo et al., 2023; Tomoi et al., 2025).

The sites were selected due to their contrasting spatial planning, infrastructure provision, and sanitation conditions relevant to the study objectives. High-income formal neighbourhoods (e.g. Parklands or Westlands) were not included because their high-rise buildings, mixed land use, and considerably higher income levels would add structural differences beyond the study's informal-formal comparison. Prior engagement by the African Population and Health Research Center (APHRC) in these communities facilitated community entry and supported trust-building for discussions of sensitive sanitation-related experiences.

Findings from our Human Right to Water (HRTW) study indicate that water insecurity persists across both settlement types but is particularly severe in Korogocho where residents face frequent service interruptions, unreliable supply, long collection times, high costs, and poor water quality, which intensify during heavy rains that often cause flooding. Water collection imposes physical, emotional, and social burdens, disproportionately affecting women, who experience greater time, safety, and stress challenges. Coping strategies are varied, but Korogocho residents are more constrained by limited storage and financial resources, relying heavily on social networks (Foellmer et al., 2026).

Floods affect both settlements, but are more profound in Korogocho, especially near the Nairobi River. During Kenya's long rains, particularly in 2024, parts of Korogocho experienced severe flooding (Kimuyu, 2024), resulting in widespread disruption, including damage and loss of homes, economic and emotional impacts, increased exposure to health and safety risks, and exacerbating already limited water and sanitation services (Foellmer et al., 2025).

In this manuscript, we refer to Jericho Lumumba and Harambee as formal settlements, and Korogocho as informal settlements.

2.2. Human right to sanitation as analytical framework

The Human Right to Sanitation (HRTS) is formally recognised as distinct from, though closely linked to, the HRTW, following the UN General Assembly resolutions in 2010 and 2015 (United Nations General Assembly, 2010a, 2010c, 2015). Its normative content is defined by the AAAAQ criteria – availability, accessibility, affordability, acceptability, and quality (Fig. 2) – alongside cross-cutting principles of non-discrimination, participation, accountability, sustainability, and impact (Giné-Garriga et al., 2017; United Nations General Assembly, 2009; 2010b).

Sanitation is commonly assessed through infrastructure-related indicators, including the type of facility and hygienic separation of human waste from human contact (UNICEF & WHO, 2018). Inadequate



Fig. 1. Map and visual characterisation of the study area: Formal (left) and informal (right) settlements in Nairobi, Kenya.

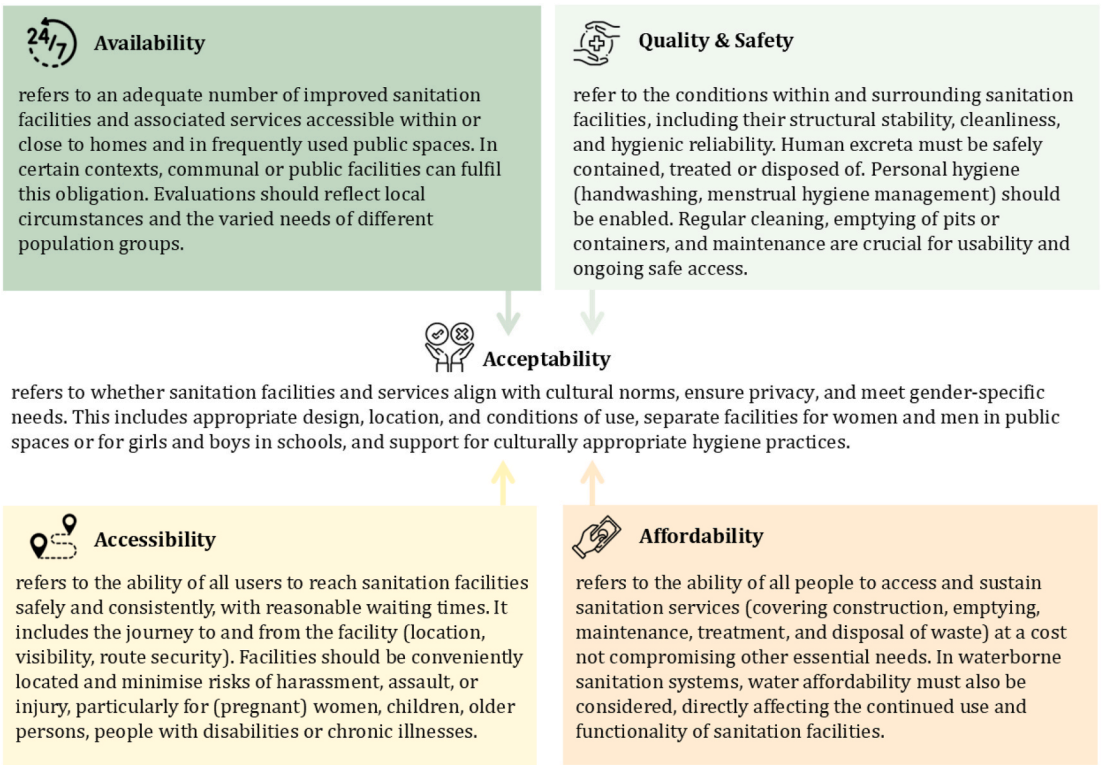


Fig. 2. Normative content of the Human Right to Sanitation (Baquero et al., 2017; Giné-Garriga et al., 2017).

sanitation describes contexts where access to sanitation infrastructure is unreliable or insufficient to support safe management of urination, defecation, and menstrual needs (Kimutai et al., 2023). Sanitation insecurity research has drawn attention to lived experiences of inadequate sanitation, highlighting how these differ across population groups and urban settings, shaped by gender, age, and broader sociocultural, environmental, and temporal contexts (Caruso et al., 2017).

Our study uses the HRTS as its analytical framework, providing internationally recognised criteria for assessing adequate sanitation. Lived sanitation experiences are foregrounded to understand how these standards are experienced or denied across settlement types and identify where, for whom, and how sanitation-related inequalities persist. This study builds on our related work on the HRTW in Nairobi (Foellmer et al., 2026), which analysed water insecurity and associated lived experiences across informal and formal settlements. It highlighted the interdependence of water and sanitation and the need for an integrated, rights-based understanding of urban service provision. The present paper extends this analytical approach to sanitation, recognising sanitation insecurity as a distinct but interconnected dimension of urban inequality, particularly in flood-prone and water-insecure environments.

2.3. Study design

This study employed a qualitative-led, comparative cross-sectional study design across informal and formal settlements to examine sanitation provision and related lived experiences. It primarily draws on focus group discussions, while a household survey provided descriptive context. Ethical approval was obtained from the Ethics Review Board at the Faculty of Geo-Information Science and Earth Observation at the University of Twente (#240656; 20.09.2024) and from the Ethics Scientific Review Committee at AMREF Health Africa (ESRC P1713/2024, 30.09.2024). A research permit was also obtained from the National Commission for Science, Technology & Innovation (NACOSTI) (NACOSTI/P/24/40935, 20.05.2024).

2.3.1. Focus group discussions

Focus group discussions (FGDs) generate exchange based on guiding questions, and encourage communications, exchange of experiences and perspectives in specific groups of persons, involving trained interviewers/moderators as facilitators (Wong, 2008). FGDs, conducted as part of a broader study on water insecurity (Foellmer et al., 2025; Foellmer et al., 2026), explored lived experiences of water insecurity, flooding, and related well-being impacts across informal and formal settlements. The FGD guide (Foellmer et al., 2025) was designed to explore how challenges related to water supply and quality, flooding, and perceived well-being were experienced in everyday life, through which sanitation-related experiences emerged as a cross-cutting theme, rather than directly probing predefined HRTS dimensions.

A growing body of literature shows that women and men experience WASH differently, as gendered household, community, and occupational roles, socio-cultural norms, and other factors (including age) shape unequal access, barriers, and lived experiences (Harris et al., 2017). Women, especially in sub-Saharan Africa, often bear responsibility for water, sanitation, and related health matters (Dickin and Caretta, 2022; Van Houweling, 2016), with inadequate WASH conditions further increasing their unpaid care burdens (Musah et al., 2026), while also facing higher disease exposure (Cole et al., 2024). Age further influences water- and health-related knowledge, attitudes and practices, and with that, of sanitation as well (Foellmer et al., 2026).

To capture diverse perspectives from residents across genders and ages, separate FGDs were conducted with women and men, and older (50+ years) and younger (18–49 years) residents across settlements. This approach draws on prior positive research experiences in Kenya and Zimbabwe, where participants felt more comfortable and open when engaging in discussions with similarly aged peers (Ogutu et al.,

2025).

2.3.2. Household survey

A household survey was administered as part of a broader study on water insecurity, flooding, sanitation, and well-being (Foellmer et al., 2025; Foellmer et al., 2026). For the purpose of this study, we used quantitative data on sanitation, including facility type and whether toilets were private, shared within a compound, or with the general public (UNICEF & WHO, 2018), alongside basic demographic information. These indicators provided descriptive contextual information aligned primarily with the HRTS dimension of availability across settlement types. Our analysis primarily draws on FGDs, which we used to explore the complexities of residents' lived sanitation experiences, including connections between issues often missed by standardised survey instruments (Wong, 2008).

2.4. Data collection

Data were collected by three trained research assistants with prior experience in the study sites, familiarity with local contexts, and fluency in Swahili, the local language. Before data collection, the research assistants completed a 4-day training covering the study objectives, design, methods (including the FGD guide and survey tool), ethical considerations, and fieldwork procedures. Following training, the survey tool was pretested within the study community by trained field staff using a convenience sample of local residents. The pre-test assessed comprehension, flow, and feasibility of administration, and adjustments were made to improve clarity before the main study. All tools were professionally translated from English into Swahili and validated by the research assistants to ensure accuracy and cultural appropriateness. Both Swahili and English versions were used according to participant preference.

Fieldwork took place between January and May 2025. In each settlement, FGDs were conducted before the household survey, beginning in Korogocho. Survey respondents and FGD participants were recruited independently, with no overlap between samples. A one-day refresher training was held before data collection in Jericho and Harambee.

Focus group and survey participants were given an informed consent form and an information sheet outlining the study purpose, key project details, potential risks and benefits, confidentiality and anonymisation procedures, data dissemination plans, and contact information. All participants were informed that their involvement was voluntary and that they could withdraw at any time.

2.4.1. Focus group discussions

FGDs were conducted in collaboration with Community Health Promoters (CHPs) at the village level, whose established trust and local networks facilitated community entry, participant recruitment, and alignment with predefined gender and age groups.

Eight FGDs were held in Swahili, four per settlement and disaggregated by gender and age. Discussions took place at a central location (partner site office), with one session at a time to ensure a comfortable environment to contribute. Each group comprised approximately eight participants, lasted 60–90 min, followed a standard protocol, and was audio-recorded with concurrent notetaking.

2.4.2. Household survey

A combination of random and systematic sampling was used in informal and formal settlements. In Korogocho ward, three villages (Grogan A, Korogocho B, Kisumu Ndogo) were randomly selected from the total number of eight villages in the ward. In Harambee ward, two neighbourhoods were chosen (Jericho Lumumba and Harambee estates). Since conversations with local representatives revealed that parts of Jericho Lumumba contained informal developments, three sections (AA, AB, AC) were purposively selected to maintain the informal–formal comparison.

The required sample was estimated at 538 households, with an additional 20% allowance for potential non-response, resulting in a target of 646 households (Foellmer et al., 2026). Household numbers for the study areas were obtained through engagement with CHPs, who reported a total of 2977 households across Grogan A (638), Korogocho B (1,196), and Kisumu Ndogo (1,143). As household lists were unavailable, these totals were used to estimate systematic sampling intervals. In Korogocho, where the study targeted at least 100 households per village, Grogan A, the area with the fewest households, was used to determine a conservative sampling interval of every sixth household. In Jericho and Harambee, every third household was selected. In each area, interviewers identified a random starting household and followed the specified sampling interval. Where a household was unavailable or declined participation, the next household was approached and the interval maintained. The final sample comprised 545 households. Because unavailable or declining households were not recorded and were replaced during fieldwork, a conventional response rate could not be calculated. Fieldwork observations indicated greater access challenges in the formal settlements, including absenteeism due to employment schedules, restricted access at household gates, and privacy concerns. The final sample was therefore smaller than the planned 646 households but exceeded the minimum required sample of 538 households. Data were collected on tablets via SurveyCTO, uploaded daily to a central server, and reviewed daily for quality and completeness.

2.5. Data analysis

To assess disparities in sanitation access from a human rights perspective in Nairobi's informal and formal settlements, the analysis applied the normative content of the HRTS as an analytical framework. Quantitative and qualitative findings were structured around the core dimensions of availability, accessibility, quality and safety, affordability, and acceptability (Fig. 2).

FGD recordings were transcribed verbatim in Microsoft Word and translated into English. The project team checked transcripts for consistency and accuracy of transcription and translation. Coding was conducted by multiple researchers. Transcripts were coded deductively according to the normative HRTS dimensions, while additional themes emerging from the data beyond these predefined categories were identified and analysed. These included community recommendations for improving sanitation and the interlinkages between sanitation, water insecurity, and flooding. A subset of researchers reviewed the analysis to ensure consistency, adequacy, and completeness.

Findings are presented with supporting quotations, highlighting contrasts between informal and formal settlements. Participants are referenced using identifiers denoting settlement type (I = informal, F = formal), age (Y = younger, O = older), gender (M = male, F = female), and participant number.

Quantitative survey data were analysed descriptively using Python 3.12.9 and used to complement the qualitative findings by providing indicators aligned with HRTS dimensions, particularly facility type and whether facilities were shared (availability).

3. Results: human right to sanitation in informal and formal settlements

3.1. Participant characteristics

Sixty-five residents (33 informal; 32 formal) participated in eight FGDs. A total of 545 households completed the survey (368 informal; 177 formal), mainly long-term residents and renters, with comparable household sizes and compositions. Women were more often respondents. Financial hardship was widespread in informal settlements, whereas it was relatively uncommon in formal settlements (Table 1).

Table 1

Socio-economic characteristics of focus group participants (A) and household survey respondents (B) (Foellmer et al., 2026).

A: Focus group participants				
Group	Gender	Age	Informal	Formal
				n
YM	Men	18-49	9	8
OM	Men	50+	8	9
YF	Women	18-49	8	8
OF	Women	50+	8	7
B: Household survey participants				
			Informal	Formal
			Percentage	Mean (min, max)
Living situation				
Years of residence				12 (0, 60)
Occupancy status				15 (0, 75)
Owner paid off	9.5		5.1	
Renter	84.5		94.4	
Free of charge by employer/relative	5.7		0.0	
Rent-free	0.3		0.0	
Respondent characteristics				
Gender				
Male	20.7		33.3	
Female	77.7		64.4	
Unknown ^a	1.6		2.3	
Household composition				
Household size			4 (1, 13)	5 (1, 11)
Number of children			2 (0, 11)	2 (0, 7)
Has members under 18 years	80.7		75.7	
Has members over 60 years	16.6		15.8	
Has disabled members	6.8		5.1	
Perceived financial situation				
Living comfortably	0.8		14.1	
Doing alright	2.2		29.9	
Just about getting by	46.7		41.8	
Finding it quite difficult	29.6		11.3	
Finding it very difficult	20.7		2.3	

^a Respondent gender was derived from household head status, reported sex of the household head, and relationship to household head. "Unknown" indicates cases where gender could not be inferred.

3.2. Availability and accessibility

Availability of sanitation infrastructure varied greatly between settlements. In formal settlements, nearly all survey respondents reportedly had private, improved facilities with piped sewer connections, and availability of facilities was not raised in FGDs. In informal settlements, most survey respondents (82.1%) reportedly used improved facilities – mainly pit latrines with slabs, flush systems connected to piped sewers, and composting toilets – whereas 18.0% used unimproved sanitation, such as pit latrines without slabs or open pits and flush systems leading to open drains. Toilets were predominantly shared within compounds (79.3%) or accessed publicly (19.6%), whereas private toilets were rare (1.1%) (Table 2).

FGD participants in informal settlements, especially women and older men, emphasised the insufficient availability of sanitation facilities. This was described as being driven by limited space from overcrowding, insecure land tenure, and landlords prioritising rental space over sanitation provision to maximise profits. Flooding was described by FGD participants as damaging sanitation infrastructure. Participants described how flood protection measures, including the demolition of structures within flood-prone areas (Foellmer et al., 2025), resulted in the removal of sanitation facilities, further reducing availability and accessibility of toilets and generating despair.

Table 2

Main sanitation facilities and access type (private, shared, public) reported in informal and formal settlements, based on household survey data collected in March–May 2025 in Korogocho (n = 368) and Jericho Lumumba and Harambee (n = 177), reported in % of respondents per response option.

	Informal	Formal
Improved sanitation		
Pit latrine with slab	42.7	0.0
Flush to piped sewer system	14.7	98.9
Flush to pit (latrine) or drum	5.4	0.6
Flush to septic tank	1.4	0.6
Composting toilet	7.6	0.0
Ventilated improved pit latrine (VIP)	4.9	0.0
Flush to don't know where	5.4	0.0
Unimproved sanitation		
Pit latrine without slab/Open pit	9.0	0.0
Flush to open drain	8.7	0.0
Bucket	0.27	0.0
Private facility	1.1	98.3
Shared with compound household	79.3	1.1
Shared with general public	19.6	0.6

“Korogocho has a lot of issues apart from water; we do not have toilets.” (I-OF-4)

“A landlord may lack the space to build the toilet because of how plots are squeezed. The landlords find it hard to sacrifice one room for a toilet.” (I-OM-4)

“[For flood response, the government] demolished houses, destroyed water pipes and toilets.” (I-OF-4)

“When the community toilet was demolished, people lost hope.” (I-YF-2)

“We had a biogas [toilet], but during the recent floods, the chief demolished it [even though it] was helping the residents here. [...] It provided good sanitation. It was very painful when it was demolished.” (I-OM-4)

Accessibility issues were rarely raised in FGDs. One younger woman in an informal settlement noted that distance and user fees can limit accessibility at night, illustrating how accessibility intersects with affordability and safety in shaping the realisation of the HRTs.

“People are unable to visit the toilet at night because the available toilet is far and it is charged a fee.” (I-YF-1)

3.3. Quality and safety

In informal settlements, FGD participants described self-constructed toilets as posing *structural and hygienic risks*. Residents described makeshift pit latrines built by converting rooms within plots, which could attract insects, or reinstalling previously demolished facilities.

“In some plots, one room is converted into a pit latrine. Toilet maggots may end up coming into my house. We brought a toilet that was recently demolished by the government.” (I-OM-7)

Unsafe disposal of human waste emerged as a persistent challenge in FGDs, particularly in informal settlements. Limited sanitation infrastructure, coupled with ineffective faecal sludge management and inadequate drainage, was highlighted as leading to waste entering rivers or the environment.

“We don't have a sewer line. Toilets are full and usually, when they are emptied, they are disposed of into the river.” (I-YF-2)

FGD participants described how limited toilet availability forced many informal settlement residents to adopt unsafe sanitation practices. Whereas no survey respondents self-reported open defecation, FGD participants described its occurrence within informal settlements.

“Most people here are tenants, not landlords. You cannot construct a toilet on someone's land. You sort sanitation out yourself. You even wake up to open defecation everywhere.” (I-YF-1)

Water insecurity was noted by FGD participants as constraining safe waste management across settlements. In informal settlements, heavy rains or floods often spread overflowing waste from full toilets into homes and streets. In formal settlements, residents linked population pressure on existing infrastructure to sewer blockages and toilet overflow, particularly in larger households sharing a toilet.

“When it rains, the drainage gets blocked. Toilets get full and overflow.” (I-OM-2)

“Toilets are blocked due to the high population. Sewage [...] always overflows.” (F-OF-3)

“When flood water blocks the sewer, toilets block. It becomes a challenge. Houses are small and big families share the same toilet.” (F-OF-6)

Insufficient water was highlighted as further compromising safety, availability, and affordability of sanitation by making toilets unusable, increasing costs for water-dependent systems, and thus limiting safe waste management. In informal settlements, FGD participants noted that open defecation or “flying toilets” become common during water shortages.

“We had to close our toilet because lack of water has rendered it non-operational.” (I-YM-1)

“When water is unavailable, the [usage] fee increases. ‘Flying toilets’ become common.” (I-YM-5)

Water insecurity was linked to *unsanitary conditions* across settlements by limiting toilet cleaning and flushing, creating additional household burdens, particularly for women, and contributing to odour concerns and reduced sanitation quality during water shortages, water supply disruptions, and flooding. In informal settlements, older women described insufficient water for flushing and cleaning toilets as resulting in strong odours across the settlement, making surrounding areas nearly impassable. In formal settlements, women particularly emphasised the household burden of rationing water for flushing, disrupting routine toilet cleaning and reducing hygiene, described as leading to unpleasant odours within households and generating annoyance, especially during high-demand periods like school holidays. Unsanitary conditions were further exacerbated by higher water prices and reduced quality of piped water during the rainy season or immediately after supply interruptions. During these periods, residents across settlements reported coping by using multiple water sources (Foellmer et al., 2026), including sewerage-contaminated water or rainwater of uncertain quality for flushing toilets and cleaning.

“Korogocho is impassable and smelly when water unavailability renders toilets unclean.” (I-OF-8)

“The toilet is dirty because people use it without water. Some use sewerage water.” (I-OF-1)

“You will have to use a very small amount of water in the toilet.” (F-OF-5)

“Immediately after rationing, water flows with sand particles. This water cannot be used for drinking and cooking. It can only be used in the toilet or cleaning surfaces.” (F-OF-5)

“Water insecurity is annoying especially during school holidays. You always have to shout in the house because people are not used to fetch water with a bucket to flush and leave the toilet as it is, then it starts to smell.” (F-YF-3)

Insufficient or unsafe water was also highlighted as affecting *hand-washing and personal hygiene* across settlements, particularly among children, increasing concerns about disease transmission. In informal

settlements, limited water near sanitation facilities restricted hand-washing, bathing, and diaper changing, which FGD participants across ages and genders associated with increased health risks, such as diarrhoeal disease among children. An older woman noted that water scarcity affects children's handwashing and household water use, as children may unknowingly use substantial amounts of water for hand-washing, leaving less for other household activities, while sometimes still eating without properly cleaning their hands, raising concerns about illness. In formal settlements, intermittent water supply was described as making it difficult for children to wash their hands after using the toilet, particularly when water had to be fetched from elsewhere, reportedly increasing the risk of water-washed disease transmission.

"A parent can be changing diapers and not bathing after due to lack of water." (I-OM-4)

"Because of rationing, someone might not be concerned about hand-washing after using the toilet. You find certain outbreaks of diarrhoea among children." (I-YF-1)

"Children may use a lot of water in cleaning their hands and decrease the amount of water in the house. Children may end up eating without cleaning hands after playing, this may lead to illnesses." (I-OF-2)

"When children lack running water after using the washroom, they will just walk away without washing their hands. They will grab something to eat that they come across without washing their hands. Next day, they experience diarrhoea." (F-YF-8)

Adults in both settlements struggled to maintain personal hygiene particularly during water shortages. Younger men in informal settlements perceived that difficulties maintaining hygiene could increase their risk of infection, including sexually transmitted infections. Younger women in informal settlements highlighted the stress of managing menstruation during water shortages.

"It becomes hard for me to maintain my hygiene. You need water to maintain hygiene, like water for bathing." (F-YM-4)

"We might not wash our hands well due to lack of water which causes health hazards." (I-OM-4)

"I engage in sexual activities and I fail to bathe when I lack water. I could be infected with some diseases such as gonorrhoea and syphilis because I am dirty." (I-YM-1)

"Water insecurity when we are experiencing the female's affairs is just stressful. You have no peace of mind" (I-YF-3).

3.4. Affordability

In informal settlements, affordability was reflected indirectly in the limited availability of sanitation infrastructure, as insecure land tenure and low household incomes constrained investment in toilets (see 3.2). In formal settlements, discussions of affordability were more directly linked to water infrastructure, particularly the ability to afford water pumps (Foellmer et al., 2026). FGDs indicated that in households without pumps, water availability within bathrooms was limited, affecting the practical use of sanitation facilities rather than their availability. Participants described relying on buckets for flushing or being unable to use showers despite the physical presence of sanitation facilities.

"For some of us, the water only comes in the kitchen [...] I have never flushed water in the toilet" (F-OF-6)

"Another challenge is getting the water up to the tank to enable the supply to the washrooms. Without a pump, you can't supply the toilet. You have to pour flush." (F-YF-8)

"[My niece] had never seen [the shower tap] function. It has affected our living standards." (F-OM-2)

"My parting shot. There is a child that is 19 years old who asked his father, 'Dad, why don't this bulb up there produce light?' It is actually not a bulb but a shower. It's because he has never seen that shower dispense water, thus he knows it's a bulb." (F-OM-9)

Ongoing costs of sanitation use were also highlighted in FGDs, particularly in informal settlements where limited water supply increased user fees for water-dependent toilets. In formal settlements, higher water prices during supply interruptions forced households to reduce water use (Foellmer et al., 2026), which could compromise the quality and safety of toilets (see 3.3), although participants did not explicitly link water affordability to toilet usability.

"When water is unavailable, the fee for toilet use increases." (I-YM-5)

Waterless, container-based toilets, such as those provided by *Fresh Life*, a social enterprise offering waterless, container-based toilets and waste collection in Nairobi's informal settlements, were discussed in FGDs in informal settlements. While these services could enhance toilet availability and accessibility, residents highlighted that ongoing service fees limited uptake among low-income households who could not afford the required payments. Households or landlords typically paid installation and monthly service fees, reported at around KES 800–850 per month. Missing payments reportedly resulted in suspended waste collection or closure or removal of toilets.

"The problem [with Fresh Life toilets] comes when contributing the monthly fee. If you run out of money, the waste won't be collected. The toilet will be used even when it is full, and eventually taken away." (I-OF-2)

Affordability therefore shapes not only toilet availability and accessibility, but also quality and safety, meaning that economic constraints directly undermine the sustained realisation of the HRTS, particularly in informal settlements.

3.5. Acceptability

Acceptability was not directly discussed in FGDs, however, aspects related to acceptability emerged indirectly across participants' accounts (see 3.2–3.4) as summarised in the following. In informal settlements, reliance on shared toilets, accessibility barriers, and inadequate sanitary conditions shaped sanitation practices, with participants describing open defecation where available facilities were inaccessible or unaffordable. In formal settlements, sanitation facilities were generally private and sewer-connected, but their use was constrained during periods of unreliable water supply. Hygiene practices were also affected across both settlement types, as participants described how water shortages constrained bathing, handwashing, toilet cleaning, and other everyday sanitation practices. Unacceptable gender-specific needs emerged across settlements, with women describing challenges related to personal hygiene, menstruation, and maintaining household hygiene during periods of water insecurity.

3.6. Community recommendations

In informal settlements, older women described improving sanitation availability as a collective, community-led effort, identifying households without toilets and encouraging owners to create space, sometimes by demolishing a room, to construct one. Such collaboration was reportedly supported through local meetings and agreements before seeking assistance from organisations, such as *Fresh Life*. These initiatives demonstrate women's leadership and mutual accountability in expanding sanitation coverage, yet, they occur alongside perceived enforcement pressures, including fear of penalties or arrest for lacking toilets. Older men, in contrast, emphasised education and oversight,

discussing efforts to raise awareness about sanitation and water issues, assess *Fresh Life* toilets condition or number, and encourage their use. These perspectives illustrate how residents collectively contribute to the HRTS realisation, while navigating persistent challenges of regulation, affordability, and funding.

"We do not construct [toilets], we come together, talk and agree. After the agreement, we call Fresh Life agents to come and set up the toilet for us. It is a must to contribute." (I-OF-2)

"We are trying to see if the number of Fresh [Life] toilets has increased since the ones installed in the past have been removed. We try to educate the residents on matters of toilets and water." (I-OM-4)

"When we find one [plot without a toilet], we advise them to demolish at least one room and construct a toilet. [...] We also attend toilet meetings. Meetings are held at the chief's camp. There is an organization that heads it [...]. It doesn't help with anything although they tell people to construct toilets in their plots. You can be arrested for not constructing. People are afraid of being arrested." (I-OF-7)

No specific sanitation recommendations emerged from participants in formal settlements. Across both informal and formal settlements, younger participants primarily raised recommendations related to water insecurity (Foellmer et al., 2026). Although not directly articulated as sanitation-related, suggested improvements in water infrastructure, reliability, affordability, and quality also have implications for HRTS realisation.

4. Discussion

Our study indicates that the HRTS remains unmet in informal and formal settlements in Nairobi, and that its realisation is undermined by the interaction between sanitation conditions, water supply interruptions, unsafe water quality, and flooding across settlement types (Fig. 3).

4.1. The HRTS in informal and formal settlements of Nairobi and beyond

Across informal and formal settlements in Nairobi, residents continue to face substantial barriers to the realisation of the HRTS,

particularly in relation to the quality and safety, affordability, availability, accessibility, and acceptability of sanitation services. These challenges are most pronounced in informal settlements (Fig. 3), where the availability of private sanitation infrastructure is very scarce. This aligns with previous evidence from Sub-Saharan Africa and South Asia highlighting reliance on shared sanitation facilities (Pessoa Colombo et al., 2023; Sprouse et al., 2025). Previous evidence suggests that shared sanitation facilities are often linked to safety concerns, especially related to night-time use and the distance to facilities (Adams et al., 2016; Aydamo et al., 2024). They are also associated with hygiene concerns arising from unsafe waste disposal, resulting environmental contamination, and health risks (Okurut and Charles, 2014; Satterthwaite et al., 2015).

In informal settlements, persistent sanitation deficiencies stem not only from infrastructure deficits due to resource and capacity constraints, but also from the historical exclusion of these communities from urban planning, service delivery, and public investment (Sinhavoy et al., 2019). Community-led initiatives (Chaudhuri, 2017; Lebu et al., 2024b; Li, 2024) often emerge to compensate for gaps in sanitation governance and financing (Chumo et al., 2023). Whereas such initiatives can improve short-term sanitation conditions, they may also reinforce inequalities, as provision becomes dependent on locally available resources, informal coordination, and financial resources instead of being consistently secured through state provision, potentially excluding households with the fewest resources (Chatterjee and Kundu, 2022; Moretto et al., 2023). Beyond household sanitation facilities, safe sanitation also depends on functioning faecal sludge management systems. In Nairobi's informal settlements, informal pit emptiers provide an important component of the sanitation service chain, but face challenges related to infrastructure, regulation, and working conditions that can limit safe waste management (Mallory et al., 2020).

Our results further highlight that the normative dimensions of the HRTS do not operate independently but are closely interrelated. Deficiencies in one dimension can constrain the realisation of others, creating cascading effects on health and well-being, as limited sanitation availability and accessibility, combined with constraints on affordability, safety, and quality, can compromise safe sanitation conditions and practices, contribute to increased exposure to faecal contamination and WASH-related health risks, and affect safety, dignity, and

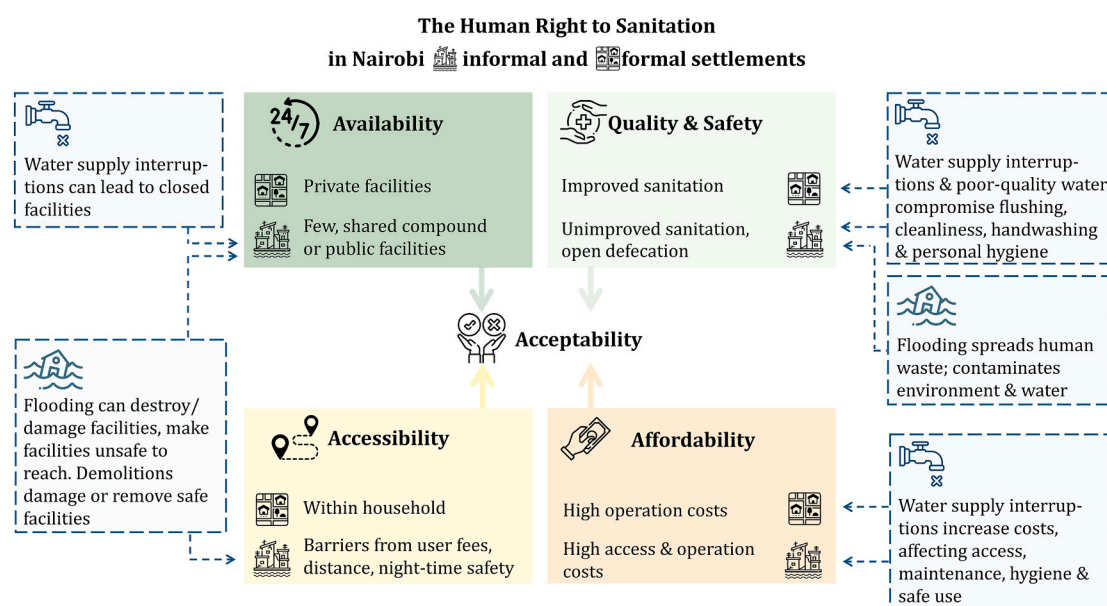


Fig. 3. The Human Right to Sanitation in Nairobi informal and formal settlements and interactions with water insecurity (too much, too little, and too dirty water) based on focus group discussions ($n = 8$ with 65 participants) and household survey data ($n = 545$) collected in Korogocho and Jericho Lumumba and Harambee in January-May 2025.

psychosocial well-being (Corburn and Hildebrand, 2015; Kimutai et al., 2023; Winter et al., 2019b). For instance, women in our informal settlements reported that at night, longer distances and user fees limited sanitation access, highlighting how accessibility intersects with affordability and safety. Inaccessibility of sanitation can lead to risky behaviour, such as open defecation and resulting environmental contamination and increased risk of exposure to disease, both for the person practicing such behaviour and the entire community (Winter et al., 2019b). Beyond these immediate access barriers, our findings suggest that affordability also influences the ability to sustain sanitation services over time, with implications for sanitation quality, safety, and acceptability. This is consistent with previous research from Korogocho showing that recurring pit emptying costs can represent an affordability barrier for shared sanitation facilities, potentially contributing to delayed emptying and unsafe sanitation conditions, with implications for environmental contamination and health risks (Tomoi et al., 2025). Although acceptability was less prominently and directly brought up than other HRTS dimensions, its relevance emerges in accounts of adverse well-being effects, and residents' frustration with persistent and cross-cutting challenges in HRTS realisation. The continued use of unsafe sanitation practices, such as flying toilets, particularly during water shortages, reflects difficult trade-offs when alternatives involve risks of violence, unsafe facilities, inaccessible routes, long waiting times, or unaffordable costs, despite awareness of associated health and environmental risks (Lusambili, 2011). This illustrates that sanitation practices are shaped not only by the availability of infrastructure, but also by the social, economic, and physical conditions under which residents access and use sanitation services.

Challenges related to (shared) sanitation voiced in our study are a major concern, particularly for extra vulnerable population sub-groups in informal settlements, such as women and girls (Chaplin, 2017; Corburn and Hildebrand, 2015; Kulkarni et al., 2017; Vogel et al., 2022), older adults, and people with disabilities (Nawaz et al., 2026), who are particularly vulnerable and more susceptible to adverse health and well-being consequences. Women and girls are disproportionately affected by shortcomings across multiple HRTS dimensions, particularly where deficiencies in availability, accessibility, quality and safety, affordability, and acceptability interact, while also most vulnerable to the adverse health effects due to their biology (e.g. menstruation and pregnancy) and often lower socioeconomic status. Lack of access can result in the use of unsafe facilities, or in walking long distances to find a place, which especially during the night can expose women and girls to physical and sexual violence (Corburn and Hildebrand, 2015). Inaccessibility of facilities, and the resulting extra time required to access sanitation, adds to gendered time and care burdens that disproportionately constrain women's productivity and opportunities (Tilley et al., 2013). Beyond the time spent accessing sanitation facilities, inadequate WASH services can increase women's unpaid domestic and care work, including maintaining household hygiene and caring for children when limited water availability compromises hygiene practices, such as handwashing, or contributes to sanitation-related illnesses, including diarrhoea. Such additional demands can negatively affect women's and girls' physical and mental health and constrain their opportunities for paid work and personal development (Musah et al., 2026).

Where sanitation remains unavailable, inaccessible, unaffordable, unsafe, or unacceptable, residents may resort to unsafe sanitation practices, including open defecation. Previous studies in Nairobi's informal settlements suggest that women's sanitation practices are driven by the cleanliness and privacy of toilet facilities, fear of victimisation, neighbourhood disorganisation (Winter et al., 2019a; Winter et al., 2018), and time of day, meaning that access to a toilet does not necessarily translate into its consistent use (Winter et al., 2019b). These unsafe coping strategies can contribute to environmental contamination (Winter et al., 2019b), while also adversely affecting mental and social health through stigmatisation, exclusion, and loss of dignity. This underlines how deficiencies across multiple HRTS dimensions can lead to

unsafe coping strategies that extend risks beyond individual users, reinforcing the wider public health and environmental implications of inadequate sanitation provision.

4.2. Interactions between unsafe sanitation and water insecurity in undermining the realisation of the HRTS

A key finding of this study is that water insecurity shapes the uneven realisation of sanitation rights by influencing whether sanitation facilities remain available, accessible, safe, acceptable, and affordable during both normal conditions and environmental shocks (Fig. 3). Although households may have nominal access to sanitation facilities, their ability to use, maintain, and benefit from those facilities is compromised when water is scarce or unreliable. More specifically, water insecurity can undermine the functioning of sanitation systems by limiting water for flushing, cleaning, and hydraulic conveyance of human waste in sanitary sewers (Hyde-Smith et al., 2022), compromising hygiene practices such as handwashing and menstrual hygiene management (Sommer et al., 2013), increasing exposure to faecal contamination, and creating additional financial burdens associated with accessing water and maintaining sanitation services. As a result, water insecurity affects both the performance of sanitation infrastructure and the dignity, safety, and well-being dimensions of sanitation rights.

Environmental shocks often magnify existing water insecurity, exposing weaknesses in water and sanitation systems that may be less apparent under normal conditions and further compromising households' ability to safely manage human waste and maintain hygiene. Flooding can damage sanitation infrastructure, mobilise faecal waste into homes, public spaces, and water sources, and interrupt desludging and other sanitation services (Berendes et al., 2019; Lebu et al., 2024a). These disruptions can reduce the availability, quality and safety, accessibility, and acceptability of sanitation services, increasing exposure to faecal contamination (Jenkins et al., 2015) and intensifying existing vulnerabilities related to dignity, privacy, and well-being.

Importantly, water insecurity and its impacts on lived sanitation experiences vary across urban settings, shaped by differences in governance arrangements, investment, and climate vulnerabilities. Specifically, in informal settlements, insecure tenure, limited public investment, fragmented service responsibilities, and reliance on informal service providers constrain households' ability to prepare for, respond to, and recover from flooding events (Howard et al., 2010; Hyde-Smith et al., 2022). Flood mitigation measures such as demolitions and relocations can further disrupt access to water and sanitation services. In some cases, interventions intended to reduce environmental risks have damaged existing infrastructure and reduced service availability (Hyde-Smith et al., 2022; Owusu-Ansah, 2016) and imposed additional financial burdens on households required to rebuild infrastructure (Foellmer et al., 2025). These findings reflect broader concerns raised in the climate and green gentrification literature that adaptation initiatives can generate new forms of exclusion by unintentionally displacing vulnerable populations or shifting them to areas with poorer services (Anguelovski and Connolly, 2024). By contrast, households in formal settlements generally benefit from more reliable infrastructure, stronger institutional mandates, and greater capacity for emergency response and service restoration (Howard et al., 2016). Water insecurity therefore amplifies the effects of pre-existing inequalities in infrastructure and service provision, contributing to unequal sanitation outcomes and realisation of the HRTS.

4.3. Policy implications for improving sanitation in Nairobi's informal settlements

Improving sanitation in Nairobi's informal settlements will likely require a transition from infrastructure-focused interventions towards systems-oriented, rights-based and climate-resilient interventions that are affordable, space-efficient, and sensitive to the needs of vulnerable

groups, including women and girls, older persons, and people with disabilities. This section discusses key policy implications arising from the sanitation challenges identified in our findings, and draws on relevant literature to identify potential directions for intervention.

Solutions should go beyond toilet availability to address all normative HRTS dimensions. Our finding that all HRTS dimensions are simultaneously challenged and closely interlinked reinforces the need for integrated approaches. However, additional context-specific evidence is needed to assess the feasibility, acceptability, and effectiveness of such approaches in Nairobi's informal settlements.

In our informal settlements, shared sanitation facilities were common and are, as shown in the literature, considered a practical option in overcrowded informal settlements with insecure land tenure (Sprouse et al., 2025). This highlights the importance of ensuring that design and management of shared facilities align with HRTS principles, particularly dignity, safety, accessibility, and acceptability. For example, adequate lighting around sanitation facilities may improve perceived safety and increase usability at night (Sprouse et al., 2024), particularly for women, children, and older residents.

Climate resilience is increasingly critical for sanitation planning amid growing environmental stressors. Our findings show that flooding and water insecurity can severely disrupt sanitation access and functionality, compounding challenges in realising HRTS, aligning with calls for solutions that remain functional under intensifying climate risks (Lebu et al., 2024a). Climate-sensitive dry sanitation solutions, such as composting toilets, have been proposed as potential options for reducing reliance on unreliable water supply and improving resilience in flood-prone environments (Dickson-Gomez et al., 2023). Similarly, raised and sealed containment systems of sanitation facilities, and decentralised treatment options adapted to dense and flood-prone environments have been identified as promising strategies for reducing contamination risks and maintaining service continuity during extreme weather events (Borges Pedro et al., 2020). Nature-based flood mitigation strategies, such as vegetated waterways or drainage corridors (Dalu et al., 2018), may also offer opportunities to manage floodwaters while reducing damage to sanitation infrastructure.

The importance of improving sanitation across the entire service chain – including emptying, transport, treatment, and final disposal – to prevent human exposure to faecal waste (Hyde-Smith et al., 2022) is underscored by our findings, showing that flooding and water insecurity exacerbate challenges in the safe management and disposal of human waste. For example, studies emphasise the values of linking sanitation infrastructure improvements with safely managed service components, such as routine maintenance, timely emptying, and behaviour change interventions, to support the quality and safety dimensions of the HRTS under both normal and flood conditions (Lebu and Cronk, 2026). The importance of coordinated cross-sectoral investments across sanitation, water supply, drainage, transport, solid waste management, and flood control systems has also been highlighted (Dickson-Gomez et al., 2023; Howard et al., 2010; Hyde-Smith et al., 2022). Such integration may be particularly important in informal settlements, where deficiencies in one service can undermine the performance and resilience of others, limiting the effectiveness of sanitation improvements alone (Narayan et al., 2021).

Affordability constraints and insecure tenure were consistently identified as barriers to sustainable sanitation improvements. Potential approaches discussed in the literature include co-investment or cost-sharing agreements between landlords and tenants, whereby tenants could contribute to facility construction and landlords provide incentives such as reduced rent or long-term tenancy agreements. More broadly, rights-based approaches may require stronger public financing mechanisms and pro-poor subsidies to reduce dependence on households' ability to pay at the point of use (Acey et al., 2019). Recognising informal settlements as legitimate urban neighbourhoods is also essential, with implications for integrating them into citywide sanitation and climate adaptation planning, rather than relying on temporary or

project-based initiatives (Bateganya et al., 2023). Finally, community action is most effective when communities are engaged as co-producers and monitors of services, rather than as substitutes for public provision (Bateganya et al., 2023; Nelson et al., 2021).

4.4. Methodological discussions and limitations, and future research directions

Several methodological considerations should be considered when interpreting our findings. First, the study was conducted in selected informal and formal settlements of Nairobi and therefore may have limited generalisability. Although the analysis compares informal and formal settlements, this classification may mask substantial heterogeneity in HRTS realisation at settlement and household levels. Informal settlements differ in infrastructure density, tenure arrangements, service access, and flood exposure, and households' adaptive capacity further varies by income, housing stability, and social networks. Additionally, some vulnerable groups, such as people with disabilities, adolescents, children, or unhoused people, were not included in the FGDs, limiting insight into their (potentially extra challenging) lived experiences. Future research should examine intra-settlement, intra-household, and intra-resident group variation in sanitation vulnerability and HRTS realisation to inform targeted interventions, including through spatial analyses that can identify geographic disparities and populations most in need of targeted support (Kim et al., 2022).

The HRTS framework was applied as an analytical framework rather than as a predefined structure for data collection. This approach enabled exploration of lived sanitation experiences beyond predefined categories, including the interlinkages between sanitation and water insecurity. However, because HRTS dimensions were not directly probed as separate topics, some dimensions, such as acceptability, were less explicitly represented in participant accounts. Future research could integrate HRTS dimensions more explicitly into data collection and further explore similarities and differences in sanitation coping strategies across informal and formal settlements, including how these practices influence human and environmental health outcomes.

The cross-sectional design provides only a snapshot, without capturing seasonal or event-based variations, limiting causal inference between water insecurity and sanitation outcomes. Although data collection occurred shortly after a period of prolonged heavy rainfall and severe flooding, which likely enhanced participants' recall of these experiences, longitudinal data collection could improve recall accuracy and strengthen attribution of health and service impacts to water insecurity. Social desirability bias may have influenced self-reported sanitation practices in the household survey, particularly for sensitive behaviours such as open defecation, potentially leading to under-reporting, though this was partly mitigated through triangulation with qualitative findings.

Our analysis did not include environmental or microbiological measurements of faecal contamination in household environments, around sanitation infrastructure, or water sources, preventing quantification of exposure and direct links between sanitation failures and disease outcomes. Non-climate-related causes of sanitation failure were also not systematically assessed. Nevertheless, the qualitative and survey findings align with established contamination pathways reported in comparable urban, flood-prone settings.

Finally, the study focused primarily on household-level experiences and did not systematically capture perspectives from and roles of utilities, local authorities, private sanitation providers, or civil society organisations in sanitation service provision and in promoting respective solutions (Curry Pereira, 2025). Accordingly, structural and institutional barriers to (climate-resilient) sanitation delivery were inferred rather than directly observed. Future research integrating service-provider and governance perspectives could strengthen understanding of how urban sanitation systems in the context of informality can be restructured and facilitate the co-creation of solutions to support progressive realisation

of the HRTS, generally and under increasing climate risk.

5. Conclusions

This study demonstrates that sanitation inequalities are shaped not only by infrastructure gaps but also by systemic vulnerabilities to water insecurity. Informal settlements face disproportionate risks due to poorly maintained facilities and unsafe waste management practices. Failing sanitation infrastructure increases vulnerability to environmental contamination and creates conditions associated with health risks, disproportionately affecting women and children. Risks are amplified by insecure tenure, low household incomes, and inadequate guidance for integrating climate resilience into sanitation planning and service provision.

Formal settlements face far lower risks due to more robust infrastructure and clearly defined institutional mandates ensuring timely maintenance and service restoration, which help mitigate flooding impacts such as sewer overflows and backflow. Nevertheless, formal settlements residents still experience sanitation challenges despite widespread access to private, sewer facilities, as intermittent, costly, and sometimes poor-quality water supplies affect flushing, toilet cleaning, handwashing, and personal hygiene. Further, population pressure on existing infrastructure contribute to sewer blockages and toilet overflows. Informal settlements lack the infrastructure, institutional support, and service mechanisms available in formal settlements, leaving residents disproportionately vulnerable to sanitation-related risks.

Addressing these disparities requires preparing the entire sanitation service chain to withstand extreme weather events and establishing rapid, coordinated response mechanisms after severe rainfall or flooding. Resilient dry sanitation systems, together with flood mitigation strategies, can enhance the safety, usability, and sustainability of sanitation infrastructure in informal settlements. These efforts should be integrated with road and drainage development, solid waste management, and measures to strengthen tenure security. Importantly, resilient and rights-based sanitation cannot be achieved through technical solutions alone. Interventions must be co-designed with residents to ensure that they reflect local priorities, practices, and needs, particularly those of groups most affected by sanitation inequalities. Affected communities possess critical knowledge of the social and spatial contexts shaping sanitation needs, making their involvement essential for developing acceptable, gender-responsive, sustainable, and context-specific solutions (Karuga et al., 2023). Achieving this requires continuous collaboration between communities, service providers, and authorities (Foellmer et al., 2026) through co-production approaches that integrate resident knowledge and priorities into sanitation planning and decision-making (Musah et al., 2026).

CRediT authorship contribution statement

Julia Foellmer: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Dennis Musyoka:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Sarah Lebu:** Writing – review & editing, Writing – original draft. **Duncan Owaga:** Writing – review & editing, Investigation. **Musa Manga:** Writing – review & editing, Writing – original draft. **Paula Janeka:** Visualization. **Caroline Kabaria:** Supervision, Project administration, Funding acquisition. **Carmen Anthonj:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Ethics statement

Ethical approval was obtained from the Ethics Review Board at the Faculty of Geo-Information Science and Earth Observation at the

University of Twente (#240656; 20.09.2024) and from the Ethics Scientific Review Committee at AMREF Health Africa (ESRC P1713/2024, 30.09.2024). A research permit was also obtained from the National Commission for Science, Technology & Innovation (NACOSTI) (NACOSTI/P/24/40935, 20.05.2024).

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We warmly thank John Mung'ei Mutinda and Kelvin Oduor Ouma for their dedicated and invaluable support in data collection, as well as in transcribing and translating the focus group discussions. We extend our sincere thanks to the community members and leaders in Korogocho, Jericho Lumumba, and Harambee, and to the Department of Health officials from Makadara and Roysambu Sub-Counties for their cooperation and facilitation during inception meetings and subsequent community engagements. We are especially thankful to all participants of the focus group discussions and the household survey for generously sharing their time, experiences, and perspectives. We thank Dr Javier Martinez and Dr Marija Bockarjova at the ITC Department of Urban and Regional Planning and Geo-Information Management, University of Twente, for their input during the early stages of project development and research design. We appreciate the designers of icons used throughout the manuscript, generously provided through Flaticon (www.flaticon.com, downloaded with a premium subscription). This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101094546. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Data availability

The data that has been used is confidential.

References

- Acey, C., Kisiangani, J., Ronoh, P., Delaire, C., Makena, E., Norman, G., Levine, D., Khush, R., Peletz, R., 2019. Cross-subsidies for improved sanitation in low income settlements: assessing the willingness to pay of water utility customers in Kenyan cities. *World Dev.* 115, 160–177. <https://doi.org/10.1016/j.worlddev.2018.11.006>.
- Adams, E.A., Boateng, G.O., Amoyaw, J.A., 2016. Socioeconomic and demographic predictors of potable water and sanitation access in Ghana. *Soc. Indic. Res.* 126 (2), 673–687.
- Anguelovski, I., Connolly, J.J., 2024. Segregating by greening: what do we mean by green gentrification? *J. Plann. Lit.* 39 (3), 386–394. <https://doi.org/10.1177/08854122241227804>.
- Aydamo, A.A., Gari, S.R., Mereta, S.T., 2024. The nexus between household water insecurity, mother's handwashing practices, and diarrheal diseases among under-five children. *J. Water Health* 22 (8), 1357–1371. <https://doi.org/10.2166/wh.2024.026>.
- Baquero, O.F., Gallego-Ayala, J., Giné-Garriga, R., de Palencia, A., J.-Fernández, Pérez-Foguet, A., 2017. The influence of the human rights to water and sanitation normative content in measuring the level of service. *Soc. Indic. Res.* 133 (2), 763–786. <https://doi.org/10.1007/s11205-016-1374-6>.

- Bateganya, N.L., Beardsley, R., Lebu, S., Atim, J., Lilian, K.S., Lahai, F., Madeira, M.M., Mulenga, O.C., Manga, M., 2023. Shifting from traditional infrastructure planning to a collaborative approach: lessons from the freetown sanitation master plan. *J. Water, Sanit. Hyg. Dev.* 13 (12), 974–985. <https://doi.org/10.2166/washdev.2023.171>.
- Beguy, D., Elung'ata, P., Mberu, B., Oduor, C., Wamukoya, M., Nganyi, B., Ezech, A., 2015. Health & demographic surveillance system profile: the Nairobi urban health and demographic surveillance system (NUHDSS). *Int. J. Epidemiol.* 44 (2), 462–471. <https://doi.org/10.1093/ije/dyu251>.
- Berendes, D.M., Leon, J.S., Kirby, A.E., Clennon, J.A., Raj, S.J., Yakubu, H., Robb, K.A., Kartikeyan, A., Hemavathy, P., Gunasekaran, A., Roy, S., Ghale, B.C., Kumar, J.S., Mohan, V.R., Kang, G., Moe, C.L., 2019. Associations between open drain flooding and pediatric enteric infections in the MAL-ED cohort in a low-income, urban neighborhood in Vellore, India. *BMC Public Health* 19, 926. <https://doi.org/10.1186/s12889-019-7268-1>.
- Borges Pedro, J.P., Oliveira, C.A. da S., de Lima, S.C.R.B., von Sperling, M., 2020. A review of sanitation technologies for flood-prone areas. *J. Water, Sanit. Hyg. Dev.* 10 (3), 397–412. <https://doi.org/10.2166/washdev.2020.019>.
- Caruso, B.A., Clasen, T.F., Hadley, C., Yount, K.M., Haardörfer, R., Rout, M., Dasmohapatra, M., Cooper, H.L., 2017. Understanding and defining sanitation insecurity: women's gendered experiences of urination, defecation and menstruation in rural Odisha, India. *BMJ Glob. Health* 2 (4). <https://doi.org/10.1136/bmjgh-2017-000414>.
- Chaplin, S., 2017. Gender, Urban Sanitation Inequalities and Everyday Lives: a Literature Review and Annotated Bibliography. Centre for Policy Research. <https://doi.org/10.13140/RG.2.2.15348.86407>.
- Chatterjee, S., Kundu, R., 2022. Co-Production or contested production? Complex arrangements of actors, infrastructure, and practices in everyday water provisioning in a small town in India. *Int. J. Urban Sustain. Dev.* 14 (1), 196–208. <https://doi.org/10.1080/19463138.2020.1852408>.
- Chaudhuri, I.N., 2017. Community mobilization for slum upgrading through sanitation in roma informal settlements in the paris region. *Front. Public Health* 5. <https://doi.org/10.3389/fpubh.2017.00213>.
- Chumo, I., Mberu, B., Wainaina, C., Muri, W., Sumba, L., Kabaria, C., 2023. Sanitation services for the urban poor: a social capital approach to sanitation challenges in informal settlements. *PLOS Water* 2 (12), e0000086. <https://doi.org/10.1371/journal.pwat.0000086>.
- Cole, S., Tallman, P., Salmon-Mulanovich, G., Rusyidi, B., 2024. Water insecurity is associated with gender-based violence: a mixed-methods study in Indonesia. *Soc. Sci. Med.* 344, 116507. <https://doi.org/10.1016/j.socscimed.2023.116507>.
- Corburn, J., 2017. Urban place and health equity: critical issues and practices. *Int. J. Environ. Res. Publ. Health* 14 (2), 117. <https://doi.org/10.3390/ijerph14020117>.
- Corburn, J., Hildebrand, C., 2015. Slum sanitation and the social determinants of women's health in Nairobi, Kenya. *J. Environ. Public Health* 2015 (1), 209505. <https://doi.org/10.1155/2015/209505>.
- Curry Pereira, R., 2025. A political ecology of wellbeing: the role of civil society organizations in supporting communities with limited access to water, sanitation, and hygiene in Brazil. <https://hdl.handle.net/10012/22422>.
- Dalu, M.T.B., Shackleton, C.M., Dalu, T., 2018. Influence of land cover, proximity to streams and household topographical location on flooding impact in informal settlements in the Eastern Cape, South Africa. *Int. J. Disaster Risk Reduct.* 28, 481–490. <https://doi.org/10.1016/j.ijdrr.2017.12.009>.
- Dickin, S., Caretta, M.A., 2022. Examining water and gender narratives and realities. *WIREs Water* 9 (5), e1602. <https://doi.org/10.1002/wat2.1602>.
- Dickson-Gomez, J., Nyabigambo, A., Rudd, A., Ssentongo, J., Kiconco, A., Mayega, R.W., 2023. Water, sanitation, and hygiene challenges in informal settlements in Kampala, Uganda: a qualitative study. *Int. J. Environ. Res. Publ. Health* 20 (12), 6181. <https://doi.org/10.3390/ijerph20126181>.
- Foellmer, J., Musyoka, D., Owaga, D., Bockarjova, M., Janeka, P., Kabaria, C., Anthonj, C., 2025. The effect of water (in)security on perceived well-being and productivity growth in urban populations of Nairobi, Kenya (Well-Being in a Sustainable Economy Revisited (WISER)). https://www.wiserhorizons.eu/fileadmin/files_to_download/DELIVERABLES/D4.3_The_effect_of_water_in_security_on_perceived_well-being_and_productivity_growth_The_case_of_African_cities_28112025_r.pdf [Project Deliverable].
- Foellmer, J., Musyoka, D., Owaga, D., Kabaria, C., Janeka, P., Anthonj, C., 2026. Water insecurity and lived experiences in Nairobi, Kenya: a comparative mixed-methods study of informal and formal settlements through the lens of the Human Right to Water. *Wellbeing Space Soc.* 10, 100419. <https://doi.org/10.1016/j.wss.2026.100419>.
- Giné-Garriga, R., Flores-Baquero, Ó., 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, L., Kleiber, D., Goldin, J., Darkwah, A., Morinville, C., 2017. Intersections of gender and water: comparative approaches to everyday gendered negotiations of water access in underserved areas of Accra, Ghana and Cape Town, South Africa. *J. Gend. Stud.* 26 (5), 561–582. <https://doi.org/10.1080/09589236.2016.1150819>.
- 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 (1), 253–276. <https://doi.org/10.1146/annurev-environ-110615-085856>.
- Howard, G., Charles, K., Pond, K., Brookshaw, A., Hossain, R., Bartram, J., 2010. Securing 2020 vision for 2030: Climate change and ensuring resilience in water and sanitation services. *J. Water Clim. Change* 1 (1), 2–16. <https://doi.org/10.2166/wcc.2010.105b>.
- Hyde-Smith, L., Zhan, Z., Roelich, K., Mdee, A., Evans, B., 2022. Climate change impacts on urban sanitation: a systematic review and failure mode analysis. *Environ. Sci. Technol.* 56 (9), 5306–5321. <https://doi.org/10.1021/acs.est.1c07424>.
- Jenkins, M.W., Cumming, O., Cairncross, S., 2015. Pit latrine emptying behavior and demand for sanitation services in Dar Es Salaam, Tanzania. *Int. J. Environ. Res. Publ. Health* 12 (3), 2588–2611. <https://doi.org/10.3390/ijerph120302588>.
- Karuga, R., Kabaria, C., Chumo, I., Okoth, L., Njoroge, I., Otiso, L., Muturi, N., Karki, J., Dean, L., Tolhurst, R., Steege, R., Ozano, K., Theobald, S., Mberu, B., 2023. Voices and challenges of marginalized and vulnerable groups in urban informal settlements in Nairobi, Kenya: building on a spectrum of community-based participatory research approaches. *Front. Public Health* 11. <https://doi.org/10.3389/fpubh.2023.1175326>.
- Kim, J., Hagen, E., Muindi, Z., Mbonglou, G., Laituri, M., 2022. An examination of water, sanitation, and hygiene (WASH) accessibility and opportunity in urban informal settlements during the COVID-19 pandemic: evidence from Nairobi, Kenya. *Sci. Total Environ.* 823, 153398. <https://doi.org/10.1016/j.scitotenv.2022.153398>.
- Kimutai, J.J., Lund, C., Moturi, W.N., Shewangizaw, S., Feyasa, M., Hanlon, C., 2023. Evidence on the links between water insecurity, inadequate sanitation and mental health: a systematic review and meta-analysis. *PLoS One* 18 (5), e0286146. <https://doi.org/10.1371/journal.pone.0286146>.
- Kimuyu, H., 2024. Nairobi Water Rationing to Continue Despite Heavy Rains: List of Estates Affected.
- Kulkarni, S., O'Reilly, K., Bhat, S., 2017. No relief: lived experiences of inadequate sanitation access of poor urban women in India. *Gend. Dev.* 25 (2), 167–183. <https://doi.org/10.1080/13552074.2017.1331531>.
- Lebu, S., Cronk, R., 2026. Bayesian network analysis infers the importance of post-construction support in maintaining the functionality of pit latrines and septic systems across 12 countries. *Environ. Sci. Water Res. Technol.* <https://doi.org/10.1039/D5EW00920K>.
- Lebu, S., Gyimah, R., Nandoya, E., Brown, J., Salzberg, A., Manga, M., 2024a. Assessment of sanitation infrastructure resilience to extreme rainfall and flooding: evidence from an informal settlement in Kenya. *J. Environ. Manag.* 354, 120264. <https://doi.org/10.1016/j.jenvman.2024.120264>.
- Lebu, S., Sprouse, L., Akudago, J.A., Twinomucunguzi, F.R.B., Rosenberg, R., Lugali, Y. S., Aine, B.M., Nguyen, J.T., Muoghalu, C.C., Semiyaga, S., Evans, B., Manga, M., 2024b. The case for shared sanitation access in informal settlements: a dialogue on science, policy, and practice integration. *PLOS Water* 3 (5), e0000243. <https://doi.org/10.1371/journal.pwat.0000243>.
- Li, E., 2024. Flushed with challenges: a case study into sanitation service delivery in a cape town informal settlement. Senior Theses, Projects, and Awards. <https://works.swarthmore.edu/theses/1043>.
- Lusambili, A., 2011. 'It is our Dirty Little Secret': an Ethnographic Study of the Flying Toilets in Kibera Slums, Nairobi (STEPS Working Paper 44). STEPS Centre.
- Mallory, A., Omoga, L., Kiogora, D., Riungu, J., Kagendi, D., Parker, A., 2020. Understanding the role of informal pit emptiers in sanitation in Nairobi through case studies in Mukuru and Kibera settlements. *J. Water, Sanit. Hyg. Dev.* 11 (1), 51–59. <https://doi.org/10.2166/washdev.2020.193>.
- Marphatia, A.A., Simiyu, S., O'Kane, M.F., Alexander, K.T., Castro, A. C. A. N. de, Azcona, G., Boni-Morkla, P.E., Bukachi, S.A., Busienel, P., Caruso, B.A., Chase, C., Chipungu, J., Dwivedi, A., Johnston, R., Khurana, I., Kome, A., Kuria, W., Labadia, J., Makoni, F., Mberu, B., Mojudmar, S., Mule, J., Sakwa, L.N., Njeri, N., Souza, F.A.O. de, Pandolfelli, L., Ramunenyiwa, P., Ray, L., Reddy, M., Saha, P.K., Sinha, U., Sinharoy, S.S., Slaymaker, T., Uguru, E., Uhl, K., Young, S.L., Ross, I., Cumming, O., 2025. Gender equality and quality of life must be central to the design and delivery of sanitation. *BMJ Glob. Health* 10 (1). <https://doi.org/10.1136/bmjgh-2024-018238>.
- McFarlane, C., 2023. Waste and the City: the crisis of sanitation and the right to citylife. <https://durham-repository.worktribe.com/output/1728967>.
- Moretto, L., Faldi, G., Rosati, F.N., Teller, J., 2023. Coproduced urban water services: when technical and governance hybridisation go hand in hand. *Front. Sustain. Cities* 4. <https://doi.org/10.3389/frsc.2022.969755>.
- Musah, C.I., Kaburia, J., Plamondon, K., Bernard, A., Nagawa, J., Ototo, E.N., Mugayehwenkyi, K., Karanja, D.S., Elliott, S.J., 2026. Gendered health inequities and policy silences: insights from deliberative dialogues on unpaid care and domestic work in Sub-Saharan Africa. *Health Place* 99, 103659. <https://doi.org/10.1016/j.healthplace.2026.103659>.
- Narayan, A.S., Marks, S.J., Meierhofer, R., Strande, L., Tilley, E., Zurbrugg, C., Lüthi, C., 2021. Advancements in and integration of water, sanitation, and solid waste for Low- and middle-income countries. *Annu. Rev. Environ. Resour.* 46, 193–219. <https://doi.org/10.1146/annurev-environ-030620-042304> (Volume 46, 2021).
- Nawaz, S., Wilbur, J., Upoma, T.A., Tabassum, K.F., Goshami, A., Podder, B., Akter, J., Hasan, M., D'Mello-Guyett, L., Shoaib, D.M., Ruuska, D., Banks, L.M., Kovats, S., Chen, S., Alam, M.-U., 2026. Extreme weather and sanitation in Bangladesh: a mixed-methods study of lived experiences of people with disabilities. *The Lancet Regional Health - Southeast Asia* 47. <https://doi.org/10.1016/j.lanseas.2026.100744>.
- Nelson, S., Drabarek, D., Jenkins, A., Negin, J., Abimbola, S., 2021. How community participation in water and sanitation interventions impacts human health, WASH infrastructure and service longevity in low-income and middle-income countries: a realist review. *BMJ Open* 11 (12), e053320. <https://doi.org/10.1136/bmjopen-2021-053320>.
- Ochako, R., Izugbara, C., Okal, J., Askew, I., Temmerman, M., 2016. Contraceptive method choice among women in slum and non-slum communities in Nairobi, Kenya. *BMC Womens Health* 16 (1), 35. <https://doi.org/10.1186/s12905-016-0314-6>.
- Ogutu, E., Sinharoy, S.S., Patrick, M., Mink, T., Macler, A., Mbogo, L., Bendit, O., Lustig, I., Irfas, J.N., Antonio, S., Ramos, G., Juarez, A., Sic, C.D., Calderón, E.,

- Ramírez, H.S.P., Lemus, J., Atandi, E., Mwangi, P., Ruto, P., et al., 2025. "If we have water, we have money": a qualitative investigation of the role of water in women's economic engagement in Guatemala, Honduras, Kenya, and Zimbabwe. *PLOS Water* 4 (12), e0000475. <https://doi.org/10.1371/journal.pwat.0000475>.
- Okurut, K., Charles, K.J., 2014. Household demand for sanitation improvements in low-income informal settlements: a case of East African cities. *Habitat Int.* 44, 332–338. <https://doi.org/10.1016/j.habitatint.2014.07.014>.
- Okurut, K., Kulabako, R.N., Chenoweth, J., Charles, K., 2015. Assessing demand for improved sustainable sanitation in low-income informal settlements of urban areas: a critical review. *Int. J. Environ. Health Res.* 25 (1), 81–95. <https://doi.org/10.1080/09603123.2014.893570>.
- Owusu-Ansah, J.K., 2016. The influences of land use and sanitation infrastructure on flooding in Kumasi, Ghana. *GeoJournal* 81 (4), 555–570. <https://doi.org/10.1007/s10708-015-9636-4>.
- Pessoa Colombo, V., Chenal, J., Orina, F., Meme, H., Koffi, J. d'Arc A., Koné, B., Utzinger, J., 2023. Environmental determinants of access to shared sanitation in informal settlements: a cross-sectional study in Abidjan and Nairobi. *Infect. Dis. Poverty* 12 (1), 34. <https://doi.org/10.1186/s40249-023-01078-z>.
- Satterthwaite, D., Mitlin, D., Bartlett, S., 2015. Is it possible to reach low-income urban dwellers with good-quality sanitation? *Environ. Urbanization* 27 (1), 3–18. <https://doi.org/10.1177/0956247815576286>.
- Sinharoy, S.S., Pittluck, R., Clasen, T., 2019. Review of drivers and barriers of water and sanitation policies for urban informal settlements in low-income and middle-income countries. *Util. Policy* 60, 100957. <https://doi.org/10.1016/j.jup.2019.100957>.
- Sommer, M., Kjellén, M., Pensulo, C., 2013. Girls' and women's unmet needs for menstrual hygiene management (MHM): the interactions between MHM and sanitation systems in low-income countries. *J. Water, Sanit. Hyg. Dev.* 3 (3), 283–297. <https://doi.org/10.2166/washdev.2013.101>.
- Sprouse, L., Lebu, S., Nguyen, J., Muoghalu, C., Semiyaga, S., Manga, M., 2025. What is driving reliance on shared sanitation in urban informal settlements? Challenges and pathways for improvement. *World Dev.* 192, 107012. <https://doi.org/10.1016/j.worlddev.2025.107012>.
- Sprouse, L., Lebu, S., Nguyen, J., Muoghalu, C., Uwase, A., Guo, J., Baldwin-SoRelle, C., Anthonj, C., Simiyu, S.N., Akudago, J.A., Manga, M., 2024. Shared sanitation in informal settlements: a systematic review and meta-analysis of prevalence, preferences, and quality. *Int. J. Hyg Environ. Health* 260, 114392. <https://doi.org/10.1016/j.ijheh.2024.114392>.
- Tidwell, J.B., Chipungu, J., Ross, I., Antwi-Agyei, P., Alam, M.-U., Tumwebaze, I.K., Norman, G., Cumming, O., Simiyu, S., 2021. Where shared sanitation is the only immediate option: a research agenda for shared sanitation in densely populated low-income urban settings. <https://doi.org/10.4269/ajtmh.20-0985>.
- Tilley, E., Bieri, S., Kohler, P., 2013. Sanitation in developing countries: a review through a gender lens. *J. Water, Sanit. Hyg. Dev.* 3 (3), 298–314. <https://doi.org/10.2166/washdev.2013.090>.
- Tomoi, H., Ingumba, B.B., Simiyu, S., Ross, I., Braun, L., Moriyasu, T., Cumming, O., 2025. Willingness-to-Pay and costs for novel manual emptying services for shared onsite sanitation facilities in an informal settlement of Nairobi, Kenya. *ACS ES&T Water* 5 (6), 3034–3044. <https://doi.org/10.1021/acsestwater.4c01244>.
- UNICEF, & WHO, 2018. Core Questions on Drinking Water, Sanitation and Hygiene for Household Surveys: 2018 Update. United Nations Children's Fund (UNICEF) and World Health Organization (WHO). <https://washdata.org/topics/methods/core-questions>.
- UNICEF & WHO, 2025. Progress on Household Drinking Water, Sanitation and Hygiene 2000–2024: Special Focus on Inequalities. <https://data.unicef.org/wp-content/uploads/2025/09/jmp-2025-wash-households-launch.pdf>.
- United Nations, 2015. Transforming our World: the 2030 Agenda for Sustainable Development. United Nations. <https://sustainabledevelopment.un.org/post2015/transformingourworld/publication>.
- United Nations General Assembly, 2009. Report of the Independent Expert on the Issue of Human Rights Obligations Related to Access to Safe Drinking Water and Sanitation, Catarina de Albuquerque. Resolution A/HRC/12/24. <https://www.refworld.org/reference/themreport/unhrc/2009/en/69700>.
- United Nations General Assembly, 2010a. Human Rights and Access to Safe Drinking Water and Sanitation. Resolution A/HRC/RES/15/9. <https://docs.un.org/en/a/hrc/res/15/9>.
- United Nations General Assembly, 2010b. Report of the Independent Expert on the Issue of Human Rights Obligations Related to Access to Safe Drinking Water and Sanitation, Catarina de Albuquerque. Resolution A/HRC/15/31/Add.1. New York. https://digitallibrary.un.org/record/685823/files/A_HRC.15.31_Add.1-EN.pdf.
- United Nations General Assembly, 2010c. The Human Right to Water and Sanitation. Resolution A/RES/64/292. https://digitallibrary.un.org/record/687002/files/A_RES.64.292-EN.pdf.
- United Nations General Assembly, 2015. The Human Rights to Safe Drinking Water and Sanitation. Resolution A/RES/70/169. <https://docs.un.org/en/A/RES/70/169>.
- Van Houweling, E., 2016. "A good wife brings her husband Bath water": gender roles and water practices in Nampula, Mozambique. *Soc. Nat. Resour.* 29 (9), 1065–1078. <https://doi.org/10.1080/08941920.2015.1095377>.
- Vogel, W., Hwang, C.D., Hwang, S., 2022. Gender and sanitation: women's experiences in rural regions and urban slums in India. *Societies* 12 (1), 18. <https://doi.org/10.3390/soc12010018>.
- Wamukoya, M., Kadengye, D.T., Iddi, S., Chikozho, C., 2020. The Nairobi Urban Health and Demographic Surveillance of slum dwellers, 2002–2019: Value, processes, and challenges. *Global Epidemiology* 2, 100024. <https://doi.org/10.1016/j.gloepi.2020.100024>.
- Winter, S.C., Barchi, F., Dzombo, M.N., 2018. Drivers of women's sanitation practices in informal settlements in Sub-Saharan Africa: a qualitative study in Mathare Valley, Kenya. *Int. J. Environ. Health Res.* 28 (6), 609–625. <https://doi.org/10.1080/09603123.2018.1497778>.
- Winter, S.C., Barchi, F., Dzombo, M.N., 2019a. Neighborhood disorganization and women's sanitation utilization practices in Mathare Valley, Kenya. *Environ. Behav.* 51 (5), 530–560. <https://doi.org/10.1177/0013916518782577>.
- Winter, S.C., Dreifelbis, R., Dzombo, M.N., Barchi, F., 2019b. A mixed-methods study of women's sanitation utilization in informal settlements in Kenya. *PLoS One* 14 (3), e0214114. <https://doi.org/10.1371/journal.pone.0214114>.
- Wong, L.P., 2008. Focus group discussion: a tool for health and medical research. *Singap. Med. J.* 49 (3), 256–260 quiz 261.