
# Indicators, Measures and Methods for Monitoring Climate Resilient WASH – Discussion Paper

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Prepared for the World Health Organization and UNICEF by the University of Leeds

In collaboration with University of Technology Sydney: Institute for Sustainable Futures, The University of Bristol, and Oxford University

**Contents**

# 1.0 Background and purpose

In 2024, WHO and UNICEF launched a joint review to identify indicators for enhanced national and global monitoring of climate-resilient WASH[1]. The results will inform future global monitoring by the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) and the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS). The joint review is supported by a consortium of academic partners led by the University of Leeds in collaboration with University of Technology Sydney: Institute for Sustainable Futures, The University of Bristol and Oxford University. The process also includes convening of a technical working group (TWG) and public consultation.

This discussion paper is an output of the ongoing project on Indicators, Measures and Methods for Monitoring Climate-Resilient WASH. Its purpose is to:

- summarise key concepts used in the WASH sector when framing climate resilience for the purposes of monitoring;
- summarise key concepts drawn from resources used to conceptualise and monitor climate resilience in other WASH-adjacent sectors;
- present a review of evidence[2] supporting indicators of climate-resilient WASH that are being used or proposed for the WASH sector; and
- reflect on the implications of the above for development of new indicators for the WASH sector.

This paper contributes to the development of a long list of candidate indicators which will be prioritized into a short list through consultations with the technical working group and the public.

[1] https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/monitoring-and-evidence/monitoring-of-climate-resilience

[2] Evidence reviews were conducted on: 1) climate resilience monitoring in WASH and WASH-adjacent sectors; 2) climate-resilient indicators for water supply; 3) climate-resilient indicators for sanitation; and 4) climate-resilient indicators for supply chain and behaviour change elements of hygiene.

# 2.0 Scope

The scope and conceptual framework of this project are laid out in the accompanying working document "Climate-resilient WASH global monitoring: Scope and definitions". This document sets out the boundaries for the consideration of climate-resilient WASH in this project. The conceptual framework identifies twelve domains of monitoring climate-resilient WASH, eight of which describe features (adaptation actions and attributes) of WASH systems, and two which specifically describe the outcomes from the perspective of service users (see **Figure 1**).

**Features of WASH systems**

- Adaptation actions by national government and subnational governments (policy, institutions, regulation and finance);
- Adaptation actions by water and sanitation service providers;
- Adaptation actions by hygiene promoters and supply chain actors;
- Adaptation actions by users;
- Adaptation actions related to coordination with solid waste and drainage; and
- Adaptation actions related to water resources and land management.

**Attributes of the WASH system**

- Attributes of water resources for water supply and receiving waters; and
- Attributes of water, sanitation and hygiene infrastructure.

**Outcomes from the user perspective**

- Water and sanitation service functioning;
- Handwashing facility functioning, available hygiene materials and disposal facilities;
- User experiences of the water and sanitation service; and
- User experience of practicing hygiene behaviours.

Some indicators of adaptation actions are already included in the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS). Items in adaptation domain areas for which data are currently being collected in the 2024/25 GLAAS survey are shown in **Table 1**.

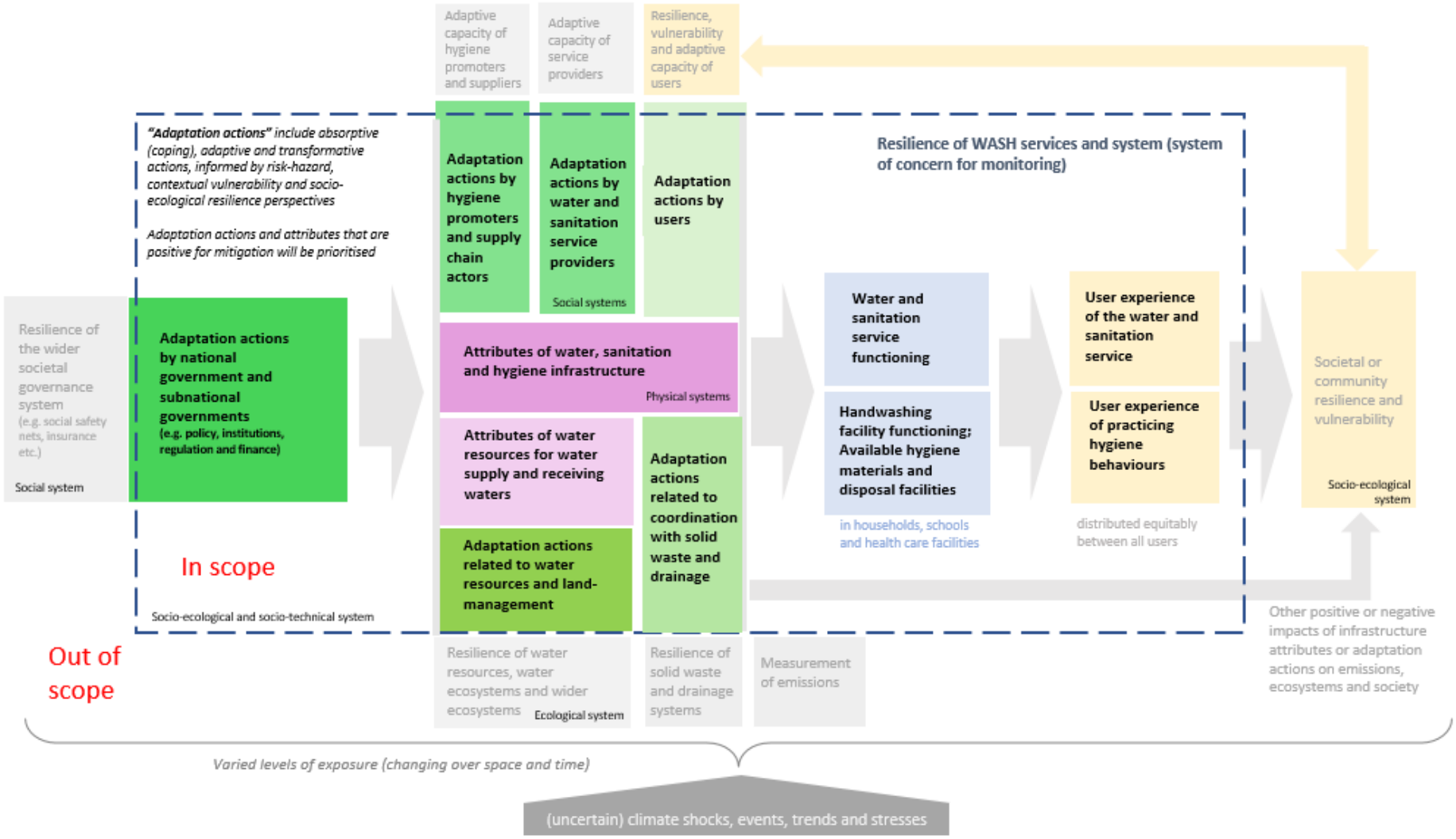


**Figure 1: Conceptual framework to guide global climate-resilient WASH monitoring**

**Table 1: Indicator areas in the adaptation domain for which data are currently being collected in the GLAAS 2024/25 survey instrument**

| |
|---|
| National monitoring tools include climate impacts and resilience indicators |
| Progress in improving water supply access is tracked for populations disproportionally affected by climate change |
| Service providers monitor climate impacts and resilience indicators |
| Sector strategies include measures to improve water supply services for populations vulnerable to climate change |
| Sector strategies include measures to improve sanitation services for populations vulnerable to climate change |
| Sector strategies include measures to improve hygiene services for populations vulnerable to climate change |
| Climate ministry has a mandated role in water supply sector review and planning |
| Inclusion of climate resilience in WASH or Water sector review and planning |
| Climate ministry has a mandated role in sanitation sector review and planning |
| Inclusion of climate resilience in sanitation sector review and planning |
| Climate ministry has a mandated role in hygiene sector review and planning |
| Inclusion of climate resilience in hygiene sector review and planning |
| Water sector policy and strategies identify climate risks and include costed climate adaptation measures |
| National government has mobilised funds to adapt the water sector to climate change |
| National adaptation plans address climate risks to water supply |
| National government has mobilised funds to adapt the sanitation sector to climate change |
| National adaptation plans address climate risks to sanitation |

# 3.0 Indicators and data requirements

## 3.1 Attributes of good indicators

The focus of this work is to make recommendations regarding global and national scale indicators for monitoring. The work was therefore framed by considering the characteristics of good indicators drawing on the complementary Align to Accelerate initiative which is seeking to identify indicators for WASH systems strengthening. The process of finalising the criteria to move from a long list to a shortlist will be developed in the coming months. To help inform the evidence reviews and the process of indicator identification, a simple set of indicator attributes was first used for reference (**Table 2**).

The specific challenges/complexities of monitoring climate resilience were also taken into account during the review process. These include the time dynamics of climate events which can vary from rapid onset, rapid change events to slow and gradual onset changes. In either case, return time periods may be long – and a true understanding of the resilience of service outcomes may only emerge over timeframes beyond normal monitoring cycles which typically span months or a few years at most. Further challenges arise because of the attribution of causes of failure is even more challenging when those failures are catastrophic. For example, a water supply network which is washed away in a flood can rarely be inspected meaningfully to identify what contributed to its destruction. Finally, it is important, but challenging to reveal differential outcomes and user experiences on the basis of climate-change related events. Disaggregation of data may go some way towards this but may not be sufficient. The axes of disequity of climate effects are poorly understood, and data are rarely disaggregated along the lines of physical geography, making it hard to identify groups living in areas with enhanced risk of flooding or drought for example.

**Table 2: Attributes of good WASH indicators – modified from Align to Accelerate Draft Discussion Paper[3]**

| Criteria | |
|---|---|
| **Usefulness to Practitioners, Policy-Makers** | Data generated by the indicator has potential to be of use to and/or addressed by policy-makers, practitioners |
| **Relevance/evidence of importance** | There is evidence that the indicator is a good measure of service outcomes under climate stressors |
| **Forward-looking** | The indicator is responsive and likely to remain relevant for at least 15 years |
| **Clearly defined** | The indicator and its data requirements can be clearly and completely defined |
| **Has reasonable potential for change over time** | The indicator measures topic(s) that have reasonable potential to change over time |
| **Is practical to measure and relies on stable and sustainable data sources** | The indicator can plausibly be measured using sustainable and affordable data collection tools |
| **Is comparable across global contexts** | The data points generated by the measurement of the indicator are comparable across different countries over time and are relevant for all country typologies |
| **Has the potential to be adapted for local use** | The indicator has the potential to be adapted for national and project scale monitoring while still being relatable at the global scale |
| **Easy to interpret and communicate** | The indicator is clear and easy to understand for policy-makers, the general public and other stakeholders |
| **Consistent with existing international frameworks and agreements** | The indicator aligns with the maximum possible number of global goals and targets so that it can be used in multiple reporting frameworks |

## 3.2 Categorising evidence

Evidence from each review has been mapped in terms of whether it is quantitative or qualitative, and tagged with the relevant climate hazard (see **Table 3**). Adaptation actions and system attributes are further clustered by general system/outcome categories for water supply, sanitation and hygiene (see **Table 3**). These general categories are a useful aid to clarify the spread of evidence and were used in a modified form to help develop the long list of indicators.

## 3.3 Special considerations for climate resilient WASH

**Is it good WASH or climate-resilient WASH?** A key consideration in reviewing evidence and seeking indicators for inclusion in the long list is to distinguish those WASH adaptation actions and attributes that relate specifically to *climate resilience* and those which relate to sustainable high quality WASH delivery even in the absence of climate change stresses. To the extent possible we have focused on, or identified the extent to which, candidate evidence and indicators relate to the *additional* characteristics of climate resilience over and above good quality sustainable WASH. However, there are examples of adaptation actions or attributes that may become urgent in the face of climate stresses or shocks and could be valid responses to increase climate resilience. An example is the reduction of non-revenue water which is de facto a good thing to do, an indictor of active management of water supply systems and certainly something that would be a no-regrets intervention even if the nature of the changing climate is uncertain. Where evidence exists to link these to climate change, they are reported in the evidence reviews. They are further considered later in the development of the long list.

[3]The A2A Discussion Paper is expected to be available in April 2025.

**Table 3: Climate Hazard and General System/Outcome Categories for Evidence Reporting**

| Climate Hazards | General System/Outcome Categories | | |
|---|---|---|---|
| | **Water Supply** | **Sanitation** | **Hygiene** |
| Changing air temperature<br>Changing precipitation patterns<br>Changing precipitation patterns; Droughts<br>Changing precipitation patterns; Floods<br>Droughts<br>Extreme Heat<br>Fire weather<br>Floods<br>Multiple hazards<br>Not explicitly climate change related[4]<br>Relative sea level<br>Severe wind | Continuity of supply<br>Volume of supply<br>Water quality | Continuity in capture (and flush)<br>Continuity in containment<br>Continuity in emptying<br>Continuity in conveyance<br>Continuity of volume proportion and level of treatment | Delivery of hygiene behaviour change programs, education and hygiene promotion messaging<br>Supply chains – access to safe, secure and preferred methods of distribution of hygiene products<br>Continuity of access to safe, secure and preferred type of product<br>Continuity of access to safe, secure, functional and preferred infrastructure for hygiene practices<br>Continuity in safe, secure, discrete and preferred services for cleaning and disposal |

**Is it incremental or transformative adaptation?** The current thinking on climate resilience is ambitious with respect to the nature of recovery from shocks and stressors and raises the possibility of reconfiguring both physical and social systems related to delivery of services. The precise nature of this ambition is laid out in the Scoping Document for this project. The recent SWA definition describes potential responses along a continuum as 'anticipate-respond-cope-recover-adapt-transform' (see **Box 1**).

However, we recognise that evidence for the more ambitious aspects of resilience (for example measures of levels of true 'adaption' or 'transformation') is likely to be harder to find (since it is less common and harder to measure) than evidence for more traditional incremental adaptation actions and attributes such as 'anticipation' and 'response'. We have been mindful of this challenge during the evidence review process.

[4] This category is included on the long list to identify indicators for which evidence has been found, but where the claimed link to climate change is tenuous.

*Box 1: Sanitation and Water for All – Definition of climate-resilient water sanitation and hygiene services*

Climate-Resilient Water, Sanitation and Hygiene (WASH) services *anticipate*, *respond* to, *cope* with, *recover* from, *adapt* to or *transform* based on climate-related events, trends and disturbances, all while striving to achieve and maintain universal and equitable access to safely managed services, even in the face of an unstable and uncertain climate, where possible and appropriate, minimising emissions, and paying special attention to the most exposed vulnerable groups.

Download at: SWA definition of climate-resilient WASH

# 4.0 Process

The work has focused on assembling existing evidence for candidate indicators which could be used across the twelve domains listed above for water supply, sanitation, hygiene or WASH as a whole. The results of four reviews, listed below, are discussed in detail in this report.

1. Monitoring climate resilience in WASH and WASH-adjacent sectors
2. Evidence for climate-resilient indicators in water supply
3. Evidence for climate-resilient indicators in sanitation
4. Evidence for climate-resilient indicators for supply chain and behaviour change elements of hygiene

The protocols for these reviews have been made available online. Key features are summarised below:

**Review on monitoring climate resilience in WASH and adjacent sectors:** This scoping review synthesises how climate resilience is conceptualised across WASH and WASH-adjacent sectors[5] (transportation, energy, telecommunications, coastal infrastructure, waste management, health systems, and education). It examines how these sectors define and measure service functioning and user experience in response to climate impacts and pertinent attributes and climate-resilient adaptation actions (or capacities) attributed to governments, service providers, users, and other stakeholders. The review aims to offer insights into how WASH-adjacent sectors monitor climate resilience that could help enhance efforts in monitoring climate resilience in the WASH sector.

**Review on water supply:** This was designed as an umbrella review to capture evidence on the impact of water supply system attributes and adaptation actions on user experience and system functioning during or after climate-related events. An umbrella review is a systematic review of existing reviews, used to synthesize evidence on a broad review question. This method was selected, since there have been several major systematic reviews within the past five years addressing closely allied questions in the general area of climate-resilient water supplies. It was felt that a review of these was a more

[5] Materials from areas with useful approaches to monitoring climate resilience, such as disaster risk reduction (DRR), finance, and urban resilience, were also reviewed. However, these were not included in the systematic screening portion of the review because they are not typically framed as discrete sectors and often span across multiple sectors.

efficient means to establish the evidence base for water supply compared to a stand-alone new systematic review. Key elements and further details of the method beyond what was initially included in the protocol are included here as **Annex 1**.

**Reviews on sanitation and hygiene:** These are systematic reviews. Both studies are focused on gathering and analysing the evidence base for the influence of a sanitation or hygiene system's technical, operational and enabling environment attributes on user experience and the functionality during and following climate extremes. Key elements and further details of the method for these reviews beyond what was initially included in the protocol are included here as **Annex 2**.

# 5.0 Emerging Evidence

## 5.1 Monitoring climate resilience in WASH and WASH-adjacent sectors

### 5.1.1 Characteristics of resources

This scoping review of monitoring climate resilience in WASH and WASH-adjacent sectors was comprised of three components. The first was a review of WASH resources, which examined key frameworks and monitoring documents specifically focused on monitoring climate resilience in the WASH sector. The second was a review of WASH-adjacent resources, which assessed key frameworks and monitoring documents in pre-defined WASH-adjacent sectors. The third was a systematic literature screening of academic articles in WASH-adjacent sectors to identify frameworks or indicators related to monitoring climate resilience.

Across WASH and WASH-adjacent sectors, identifying resources with practical examples of monitoring climate resilience was challenging (**Figure 2**). Many resources focused on broad conceptualisation of resilience, lacking explicit mention of climate stressors. For resources that specifically addressed resilience to climate stressors, few resources linked these concepts to structured monitoring approaches. One hundred and fifteen resources were identified and screened in the review of WASH resources, but only 15 contained practical monitoring indicators, reflecting a general gap in operationalising climate resilience within the sector. These resources predominantly focused on low- and middle-income countries (LMICs) when geographical context was specified and were heavily weighted toward water-related indicators, with sanitation and hygiene receiving less attention. Indicators spanned nine major themes, including policy, financing, infrastructure, and governance, but varied in specificity and applicability.

The review of WASH-adjacent resources identified even fewer relevant resources because most lacked a climate-specific focus or practical monitoring approaches. Health systems were the primary exception, contributing the majority of extracted indicators. The WASH-adjacent academic literature review reinforced these findings, with transportation and energy emerging as the WASH-adjacent sectors most focused on monitoring climate resilience after health systems. Across all resources and literature reviewed, major themes emerged regarding gaps in climate resilience conceptualisation, monitoring and methodological detail on how these approaches should be applied.

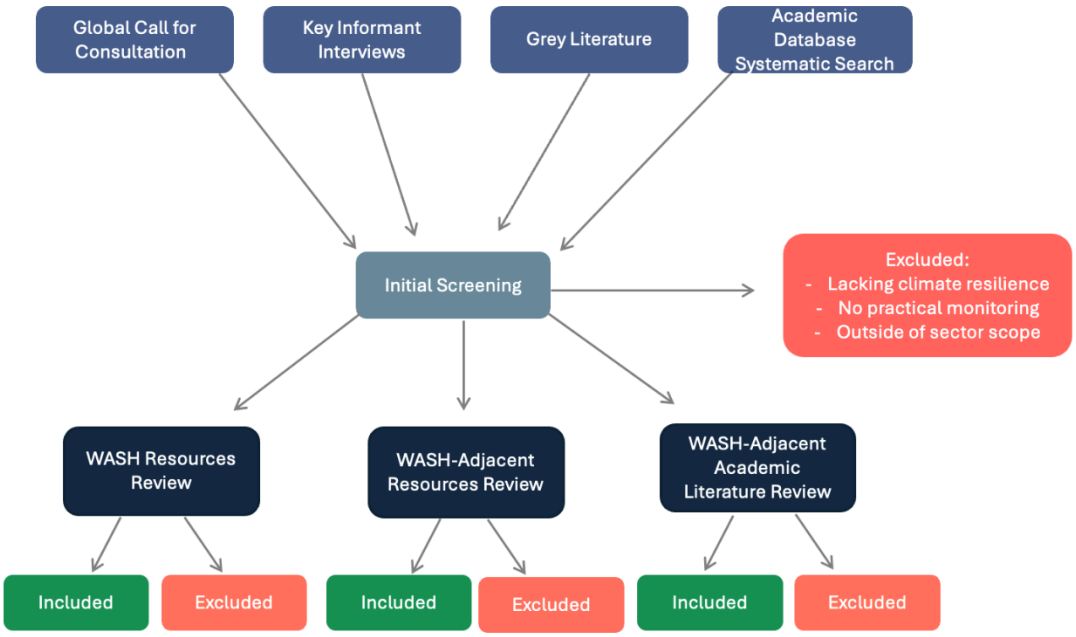


**Figure 2: Data sources and general screening process for the review of WASH and WASH-adjacent resources**

### 5.1.2 Conceptualisation of climate resilience

This project has developed a set of definitions, including of climate resilience, which are set out in our Scope and Definition Document. Our work is strongly informed by the Sanitation and Water for All definition of climate-resilient WASH (see **Box 1**). The SWA definition is not included in the outputs from this review because it does not include proposed indicators for monitoring purposes.

Conceptualisations of climate resilience varied across the included resources, with climate resilience explicitly addressed primarily in resources from the health systems and WASH sectors. Resources from other WASH-adjacent sectors commonly framed resilience around sector or system resilience more broadly, with climate considered as one of multiple stressors rather than the primary focus. For example, several WASH and health system resources explicitly defined resilience as the capacity of systems to anticipate, respond to, cope with, recover from, and adapt to climate-related shocks and stresses (**Table 4**), while other documents adopted similar definitions but applied them more generally to the ability of a system—whether a sector, organization, or community—to prepare for, withstand, adapt to, and recover from disruptions (Yang et al., 2019). In these broader definitions, climate was considered alongside other disruptions such as technical failures, terrorism, and cyber risks (Mutani and Todeschi 2018; Rezun et al., 2019; Jasiunas et al., 2021). The variation in how resilience is defined and conceptualised highlights an ongoing discourse within the WASH sector on whether climate-resilient WASH should be a distinct consideration or either falls within general WASH system resilience, or simply an extension of well-functioning, or "good," WASH systems.

Findings from the review suggest that while adjacent sectors often include climate as one of the many stressors within general resilience frameworks, it is important for the WASH sector to consider climate resilience with more explicit attention. Many of the reviewed resources that addressed sector resilience but treated climate as a secondary consideration were excluded due to their lack of practical

application, underscoring a limitation in their ability to provide targeted strategies for monitoring climate resilience. Among the resources included in the review, resources with more general resilience monitoring approaches tended to focus solely on infrastructure resilience. A potential implication of these findings is that setting climate resilience within either general WASH resilience conceptualisation or "good" WASH, risks monitoring approaches being too broad and reactive, potentially overlooking the compounding impacts of climate that uniquely affect WASH systems. Conversely, some actions and attributes that align with general "good" WASH practices may be excluded from conceptualisations of climate-resilient WASH, even though they are critical for anticipating, responding to, coping with, recovering from, and adapting to climate-related shocks and stresses.

**Table 4: Definitions specific to climate resilience identified within WASH and WASH-adjacent resources included in the review**

*Note:* These resources were included because they focused on monitoring climate resilience, and the definitions reflect how they approached that process.

| Definitions specific to climate resilience[6] | Sector | Name of document(s) featuring definition |
|---|---|---|
| The ability of people and systems to anticipate, adapt to and recover from the negative effects of shocks and stresses (including natural disasters and climate change) in a manner that reduces vulnerability, protects livelihoods, accelerates and sustains recovery and supports economic development, while preserving cultural integrity | WASH | UNICEF-guidance note shift to climate resilient wash programming; WASH Climate Resilient Development Strategic Framework 2022 |
| Climate resilient WASH refers to WASH services and behaviours that continue to deliver benefits, or that are appropriately restored, within a changing climate context and despite climate induced hazards. | WASH | Integrating climate resilience with WASH system strengthening; WaterAid Aim 1 WASH system building block assessment tool |
| Climate resilient health systems are those that are capable of anticipating, responding to, coping with, recovering from, and adapting to climate- related shocks and stresses, so as to bring about sustained improvements in population health, despite an unstable climate | Health systems | WHO 2022 Measuring the climate resilience of health systems |
| Climate resilient and low carbon health systems are those capable of anticipating, responding to, coping with, recovering from, and adapting to climate-related shocks and stress, while minimizing GHG emissions and other negative environmental impacts to deliver quality care and protect the health and well-being of present and future generations. | Health systems | WHO 2023 Operational framework for building CR and low carbon health systems; 2024 Climate change and health: Resilience and GHG emissions index |

Another key characteristic in the conceptualisation of climate resilience within the review was not only the definition of resilience but also its relationship to related concepts such as vulnerability, adaptive capacity, robustness, and redundancy. Several reviewed sources developed climate resilience resources that focused on measuring vulnerability (Poo et al., 2021; Alipour and Minor 2024).

[6] Some frameworks or monitoring resources are not shown here because, while critical to the sector, they are not included in the evidence review. This is usually because they do not propose monitoring frameworks and indicators. An example would be the SWA definition of climate-resilient WASH.

However, resilience and **vulnerability** are not strictly inverse— in the sense that reducing vulnerability does not necessarily mean a system is more resilient, just as a system could demonstrate resilience despite certain vulnerabilities. While vulnerability is important, assessing and addressing vulnerability on its own does not fully capture resilience, and resilience monitoring approaches that primarily assess vulnerability may overlook key adaptation actions or attributes of resilience. **Adaptive capacity** was another concept that varied in how it was positioned within resilience monitoring approaches, sometimes treated as a component of resilience and other times as a subset influencing measures of vulnerability. Similarly, **redundancy** was conceptualised in different ways—some resources treated redundancy as a normal system function, while others considered redundancy to be a designated resilience mechanism that enhanced a system's ability to withstand disruptions. The perspective through which these terms were defined and utilised, as well as other concepts such as robustness, flexibility, and efficiency, affected how resilience was operationalised and monitored within included resources. These distinctions influenced the selection of indicators used, determining whether resilience, for example, was measured through factors present before an event, such as socioeconomic conditions and system capacity, or through system preparedness and the ability to maintain function despite disruptions. This, ultimately, shaped how resilience was assessed and applied within sectors.

Throughout the different conceptualisations of resilience to climate-related stressors, the focus was generally on high-impact, low-probability events or short-term shocks (Panteli and Mancarella 2017; Zhang et al., 2024). Monitoring efforts placed an emphasis on measuring how the system responded to and coped with distinct events, rather than longer-term strategies for recovering, adapting and transforming systems under evolving climate conditions. This framing prioritised immediate response actions, often overlooking approaches that address gradual, cumulative climate impacts and support sustained system functionality and improvement over time.

### 5.1.3 Measuring climate resilience

In addition to the wide variation in how climate resilience was conceptualised, the reviewed resources differed significantly in their objectives or outcomes measured, the types of indicators used, and the level of detail provided on data sources and collection methods. While some resources clearly outlined structured indicators or sub-indicators, others provided broad principles or objectives without specifying measurable metrics that could be used to monitor resilience in practice. Across sectors, key gaps emerged in the availability of guidance on data sources, collection methods, and indicator standardisation, making it difficult to compare resilience measures across different contexts. The lack of clarity on how to gather and interpret data often limited the applicability and comparability of indicators, particularly when resources did not specify data format, indicator type (e.g., nominal, ordinal, open text), frequency of data collection, or analytical methods for tracking temporal or spatial changes in resilience. Additionally, resources did not explicitly address uncertainty in climate projections. Where indicator thresholds were used, they were often based on predefined ranking systems specific to a framework (e.g., categorical scales such as 1, 2, 3) rather than flexible or dynamic thresholds that could account for increasing climate variability.

Indicators extracted from the included resources aligned with several broad thematic categories, such as governance and institutional capacity, finance and economic considerations, monitoring and evaluation, infrastructure and service reliability, health systems and workforce, emergency preparedness and risk management, and community engagement and social systems. However, their emphasis varied considerably across sectors. Aligned with the broader trend in resilience conceptualisation, indicators were predominantly focused on measuring infrastructure resilience, with fewer addressing social, governance, or adaptive dimensions. While some resources conceptualised climate resilience beyond infrastructure to include elements of socio-ecological systems, there was a

lack of specific indicators designed to measure resilience within these domains. Many of these indicators remained conceptual rather than operational, limiting their applicability for resilience monitoring.

This trend may be influenced by the fact that many indicators were derived from risk-hazard frameworks, which prioritise physical infrastructure and technical system performance over social and institutional dimensions of resilience. While some frameworks included indicators related to pre-existing conditions that shape how systems or communities experience climate stressors, these were not always clearly integrated with indicators assessing a system's ability to withstand, recover from, or adapt to such stressors.

A specific gap in resilience monitoring was the lack of user experience indicators, as most resources relied on technical and infrastructure-based measures rather than capturing subjective or community-level experiences of climate stressors. To address this, reviewing metrics not specific to climate resilience, such as the Household Water Insecurity Experience (HWISE) and Individual Water Insecurity Experience (IWISE) indices,[7] could strengthen climate resilience monitoring by incorporating user-centred perspectives on water reliability, availability, and access.

Another gap included the lack of indicators considering service provider capacity and their ability to influence resilience, particularly in relation to risk assessment, contingency planning, and operational decision-making. While some resources included indicators for infrastructure recovery times following climate events, they rarely accounted for factors that support faster recovery, such as stockpiling spare parts at the community or district level or ensuring flexibility in supply chains. Similarly, utility performance indicators related to service reliability (e.g., duration and frequency of water outages, ability to maintain services under climate stress) were underrepresented, despite their relevance in assessing climate resilience in WASH systems. Expanding the inclusion of service provider capacity and operational resilience indicators could improve the ability to monitor resilience beyond infrastructure performance alone.

Across sectors, the majority of indicators focused on measuring response to and coping with climate events rather than long-term resilience-building, despite many climate resilience definitions including language related to long-term resilience. Fewer indicators explicitly captured long-term aspects of resilience including adapting, learning, or transforming, reflecting a predominant focus on restoring services after climate events rather than strengthening systems to withstand future stressors. Additionally, indicators addressing slow-onset stressors such as sea level rise or prolonged drought were underrepresented, and when drought was included, it was often framed as a discrete event rather than a chronic, evolving stressor requiring different monitoring approaches.

Lastly, indicators capturing interlinkages across different sectors were also limited, with most resources structuring indicators within a single sector rather than accounting for cross-sectoral dependencies. While some indicators referenced interconnections—such as the dependence of critical services on energy supply (Cardoso et al., 2020)—their measurement remained sector-specific. These metrics were often descriptive or binary (presence/absence of interactions) and focused on identifying dependencies rather than monitoring adaptation actions or system attributes that could enhance resilience. As a result, few indicators explicitly assessed cascading or compounding effects across sectors or the role of cross-sectoral planning and integration in shaping climate resilience.

[7] What Are the WISE Scales?: Water Insecurity Experiences (WISE) Scales - Northwestern University

# 5.2 Water supply

## 5.2.1 Characteristics of reviews

Nineteen eligible reviews were identified from the database search (see Annex 1). Eight (42%) of these were systematic reviews that provided their search strategies and eligibility criteria (**Table 5**).

*Context*

Of the 19 reviews, 17 (81%) included evidence from both urban and rural settings, 3 focused on urban water supplies and 2 on rural water supplies. The majority of the reviews (n=12, 63%) had a global focus, three focused on Africa, one on Europe, one on small island developing states (SIDS) and two were country specific.

*Climate hazards*

Decreased precipitation or drought, leading to water scarcity, were included in all 19 reviews. Other hazards mentioned were sea level rise or ingress of salinity into coastal waters (n=5), flooding (n=3), heavy rainfall (n=3) and wildfires (n=1).

*Adaptation actions and system attributes*

The reviews documented adaptation actions taken by service providers (n=15, 79%), national or sub-national government (n=12, 63%), and users (n=11, 58%) in response to climate hazards. Eight reviews (42%) included adaptation related to water resource or land management in watersheds. Attributes of water supply infrastructure and water resources were reviewed by 10 (53%) and 3 (16%) articles, respectively.

*Outcomes*

Ten (53%) reviews reported evidence on the impact of actions or attributes on water supply functioning or user experience, qualitatively.

*Data extraction from primary literature*

Screening of primary studies included in the 19 reviews revealed 108 articles, from which evidence was extracted on adaptation actions, attributes and outcomes.

**Table 5: List of reviews included for analysis for water supply**

| Study | Reference Number | Title | Review type | Urban/Rural or mixed | Global or location | Climate extreme |
|---|---|---|---|---|---|---|
| Leal Filho et al 2022 | 1 | Understanding responses to climate-related water scarcity in Africa | systematic | mixed | Africa | Flood/ drought/SLR |
| Elgendy et al 2024 | 2 | Review of Climate Change Adaptation Strategies in Water Management | systematic | mixed | Global | Flood/drought |
| Azhoni et al. 2018 | 3 | Adapting to climate change by water management organisations: Enablers and barriers | literature review | mixed | Global | Drought |
| Bailey et al. 2024 | 4 | Participatory justice and climate adaptation for water management in Small Island Developing States: a systematic literature review and discussion | systematic | mixed | Low Middle income/ small island states | Wind/storm/ drought |
| Bartlett et al. 2023 | 5 | Adaptation strategies for climate change impacts on water quality: a systematic review of the literature | systematic | mixed | Global | Flood/rain/SLR/ drought/ heat |
| Haque and Nahar 2023 | 6 | Bangladesh: Climate Change Issues, Mitigation, and Adaptation in the Water Sector | literature review | mixed | Bangladesh | SLR/drought |
| Olmstead et al. 2014 | 7 | Climate change adaptation and water resource management: A review of the literature | literature review | mixed | Global | Drought |
| Howard et al. 2016 | 8 | Climate Change and Water and Sanitation: Likely Impacts and Emerging Trends for Action | literature review | mixed | Global | SLR/drought |
| Herman et al. 2020 | 9 | Climate Adaptation as a Control Problem: Review and Perspectives on Dynamic Water Resources Planning Under Uncertainty | literature review | mixed | Global | Drought |
| Khan et al. 2015 | 10 | Extreme weather events: Should drinking water quality management systems adapt to changing risk profiles? | literature review | mixed | Global | Flood/rain/SLR/ drought |

| Study | Reference Number | Title | Review type | Urban/Rural or mixed | Global or location | Climate extreme |
|---|---|---|---|---|---|---|
| Lede and Meleady 2018 | 11 | Applying social influence insights to encourage climate resilient domestic water behavior: Bridging the theory-practice gap | literature review | mixed | Global | Drought |
| Papadaskalopoulou et al. 2015 | 12 | Review and assessment of the adaptive capacity of the water sector in Cyprus against climate change impacts on water availability | literature review | mixed | Cyprus | Drought |
| Rickert et al. 2019 | 13 | Including aspects of climate change into water safety planning: Literature review of global experience and case studies from Ethiopian urban supplies | literature review | mixed | Global | Rain/SLR/ drought |
| Vinagre et al. 2023 | 14 | How Can We Adapt Together? Bridging Water Management and City Planning Approaches to Climate Change | systematic | urban | Global | Drought |
| Zvobgo et al. 2022 | 15 | The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment | systematic | mixed | Africa | Drought |
| Garnier and Holman 2019 | 16 | Critical Review of Adaptation Measures to Reduce the Vulnerability of European Drinking Water Resources to the Pressures of Climate Change | literature review | urban | Europe | Drought |
| Larsen et al 2016 | 17 | Emerging solutions to the water challenges of an urbanizing world | literature review | urban | Global | Drought |
| McDowell et al 2019 | 18 | Adaptation action and research in glaciated mountain systems: Are they enough to meet the challenge of climate change? | systematic | rural | Global | Drought |
| Wiederkehr et al 2018 | 19 | Environmental change, adaptation strategies and the relevance of migration in Sub-Saharan drylands | systematic review | rural | sub-Saharan Africa | Drought |

### 5.2.2 What is being measured?

One hundred and eight primary studies across the 19 reviews documented system attributes and their response to a climate hazard, or adaptation actions by stakeholders in response to or in preparation for a climate hazard. The studies covered both utility-managed piped supplies and small community-managed supplies.

*Adaptation actions and attributes*

A summary of the adaptation actions and attributes reportedly measured in the primary literature associated with these studies is summarised in **Table 6** mapped against climate hazards and showing general system/outcome categories (**Table 3**) where these are reported or measured.

Most studies listed a combination of adaptation actions taken by national or sub-national government (n=43), service providers (n=42) and users (n=20). There was relatively less focus on actions related to water resources and land management in watersheds (n=14), attributes of infrastructure (n=11) and attributes of water resources (n=6).

Low rainfall or drought was the most common hazard included in the literature, with over 90 studies documenting adaptation actions. The most common actions reported by sub-national government stakeholders were on developing drought response plans, augmenting supply, and bylaws for water allocation and tradeable water rights. Local authorities manage demand mainly through passing local restrictions for water use (both voluntary and mandatory), increasing tariffs and communication campaigns.

Service providers support these local regulations by enforcing higher water pricing and water restrictions during scarcity, accessing alternative water resources and increasing storage capacity of surface reservoirs. Household water scarcity is addressed through accessing alternative water sources, new service providers, and reducing consumption either through rationing or water-efficient appliances.

Five studies presented attributes of aquifers that were most susceptible to falling groundwater levels and scarcity. There is qualitative evidence that aquifer permeability and residence time were both positively correlated with better groundwater accessibility during drought.

The relatively little documentation on flood adaptation was limited to flood diversion infrastructure, and catchment management to minimize sediment and nutrient transport to surface waters.

One study reported on actions by service providers to minimize treatment disruption after a wildfire in a forested catchment, that included switching to alternative sources and mechanisms to shutdown treatment based on upstream water quality changes.

**Table 6: Mapping of evidence of attributes and adaption actions against climate change effect and service continuity outcomes for water supply[8]**

| Climate Change Effect | Potential impact on water supply | Water supply outcomes | | |
|---|---|---|---|---|
| | | Continuity of supply | Volume of supply | Water quality |
| More intense precipitation/ flooding | Reduced source water quality | | | Flood diversion channel (33)<br>Modifying reservoir operation (87*)<br>Catchment management plans (61) |
| | Reduced efficiency of water treatment | | | Water treatment processes (88) |
| | Damage to infrastructure | Decentralisation of governance and formalisation of informal community institutions (41) | Reservoir operation (98) | |
| More intense windstorms | Damage to infrastructure | Household water storage (70) | | Water treatment processes (90) |
| | Saline intrusion into coastal groundwaters as a result of storm surge | | | |
| Declining rainfall/ long dry spells/ more intense drought | Water scarcity | | Tradeable water rights (7*, 24*, 28*) | |
| | | Drought management plans (5, 37) | | |
| | | Introducing voluntary restrictions for consumptive and non-consumptive water use (5, 37, 42) | Introducing voluntary restrictions on water use (18, 23, 85, 95*, 103) | |
| | | Reducing water use for non-consumptive use (45) | Introducing mandatory restrictions on water use (85) | |

[8]Numbers in brackets refer to document reference in the evidence review. Items marked with an asterix are modelled, not measured, results.

| Climate Change Effect | Potential impact on water supply | Water supply outcomes | | |
|---|---|---|---|---|
| | | **Continuity of supply** | **Volume of supply** | **Water quality** |
| Declining rainfall/ long dry spells/ more intense drought | | Summer pricing (5)/increased tariffs (37) | Tariff reform (30) | |
| | | | Rebate for water efficient appliances (95*, 99) | |
| | | | Subsidy for greywater treatment systems (103) | |
| | | | Subsidy for drilling boreholes for non-consumptive use (103) | |
| | | Penalties for high-volume users (37) | Water conservation tax (85) | |
| | | Consumer education and communication (5, 37) | Consumer education and communication (27, 85, 95*, 96, 105, 106, 107) | |
| | | | Reduced leakage in distribution network (16*, 17*, 18, 64, 85, 103) | |
| | | Size of water storage (76, 84) | Building additional storage (17*, 60*, 63) | |
| | | Wastewater reuse for non-consumptive use (29) | Wastewater reuse (17*, 60*) | |
| | | Installing devices to cut off supply in case of excessive use or leaks (37) | Installing water-efficient devices (17*, 97, 99) | |
| | | | Improved metering and billing (17*) | |
| | | | Desalination (18, 60*, 63, 111) | |
| | | | Desalination (102) | |
| | | | Pipe replacement (18)/plumbing retrofitting (95*, 103) | |
| | | | Drilling household boreholes for non-consumptive supply (18) | |
| | | Regional water reallocation (20) | Flexible water allocation laws (28*) | |

| Climate Change Effect | Potential impact on water supply | Water supply outcomes | | |
|---|---|---|---|---|
| | | Continuity of supply | Volume of supply | Water quality |
| Declining rainfall/ long dry spells/ more intense drought | | Water allocation based on groundwater levels (66*) | | |
| | | Creation of a resilience taskforce (20)<br>Creation of an online water management dashboard (20) | | |
| | | Water transfer between basins/dams (20, 37) | Balance storage between reservoirs (23) | |
| | | | Modifying reservoir operation (23, 26) | |
| | | | Artificial groundwater recharge (25) | |
| | | Water rationing (29) | Regional/local strategies for rainwater harvesting for non-consumptive use (32*, 111) | |
| | | Alternative supplies for consumptive use (29, 45) | HH-level rainwater harvesting for non-consumptive use (45, 49) | |
| | | Shifting gender roles in water collection (45) | Rainwater harvesting for non-consumptive use (40*, 53) | |
| | | Decentralisation of governance and formalisation of informal community institutions (41) | Water rationing (103) | |
| | | Accessing high-yield aquifers (82, 83) | Dual reticulation system to supply recycled stormwater and wastewater (51) | |
| | Changes in contaminant transport and die-off in source water | | | Water treatment process and dosing (88) |
| | Wildfires | | | Switching to alternative source (89)<br>Monitoring changes in water quality at intake (89) |

| Climate Change Effect | Potential impact on water supply | Water supply outcomes | | |
|---|---|---|---|---|
| | | Continuity of supply | Volume of supply | Water quality |
| | | | | Automatic shutdowns (89) |
| | | | | Flexibility in treatment processes (89) |
| Sea level rise | Saline intrusion into coastal groundwaters | | Dune filtration (57) | Dune filtration (57) |
| | | | | Well depth and siting (75) |
| | Inundation of infrastructure | | | |
| Increasing temperature | Algal blooms in surface waters | | | |
| | Glacier melt | Access to rain-fed rivers (81*) | | |

**Legend**

| | |
|---|---|
| | Adaption action by users |
| | Adaption actions by service providers |
| | Adaption actions by national and subnational governments |
| | Attributes of infrastructure |
| | Attributes of water resources |
| | Adaptation actions related to water resources and land management |

## 5.3 Sanitation

### 5.3.1 Characteristics of evidence

A systematic review was conducted to explore the extent to which technical, operational, and enabling environment attributes impact sanitation and hygiene user experience and system functioning during and following extreme weather events (see Annex 2 for details).

After screening five online databases, nearly 4000 records were identified. After removing duplicates, 3474 records were screened, and 225 abstracts were reviewed. In 57 cases, the full-text document was assessed for eligibility, leading to a final set of 17 records included in the review.

The articles included in the review are shown in **Table 7** and their characteristics are summarised in **Table 8**.

The articles which provide evidence that a given system attribute or adaption action impacts system performance or user experience during and following a climate extreme can be categorised into two main clusters. These clusters consist of sanitation studies derived from engineering literature (n=6) and those from international development literature (n=11).

The first group, predominantly focuses on attributes and adaption actions relating to sewered systems in high-income contexts, featuring studies which are generally more quantitative in nature. These studies tend to adopt a traditional engineering resilience approach focussing on robustness, redundancy and reparability (Wang et al., 2022). Many of the studies in this category that address adaptation actions and attributes of utility scale systems rely on modelling rather than empirical data and were therefore excluded from the review. These make reference to industry documents, which are also often based on modelling rather than empirical evidence, and many of these are inaccessible or at least hard to access.

In slight contrast, the second cluster centres on low-income contexts, and are largely based in low- and middle-income countries, analysing non-sewered sanitation systems and developmental approaches to resilience. While these studies also take an engineering perspective, they adopt more qualitative approaches to explore the relationship between the attribute or action and the resilience outcomes. This approach allows for a deeper understanding of the user experience outcomes which were missing entirely from the first cluster. This focus on user involvement may arise from the fact that many of the system attributes or adaptation actions in this group are either directly controlled or heavily influenced by the user or household.

The most prominent climate hazard studied was the changing frequency and intensity of rainfall, often resulting in pluvial flooding (n=16), one of these studies included saltwater intrusion due to coastal flooding. Sea level rise (SLR) as a long-term climate hazard was not present in the included literature. However, other longer-term hazards such drought (n=4) and extreme heat (n=1) where present in the analysis. Four studies considered several climate hazards.

One third of the literature was based on case studies in high-income contexts, distributed evenly across North America, Europe, East Asia and Oceania. All of these studies relate to sewered systems (n=5) or treatment facilities (n=1). Eight studies were conducted in low-income settings, all of which addressed adaption actions of attributes relating to latrines or toilets, with five of these studies carried out in Bangladesh. Four studies were focussed in UMICs (n=2) or LMICs (n=2). One study contained case studies from four discrete countries, relating to several income classification levels but only one study presented evidence.

**Table 7: List of articles included in analysis for sanitation**

| Study | Reference Number | Study Location | Sewer/non-sewered | Position along sanitation value chain | Study country classification by income[9] | Climate hazard studied |
|---|---|---|---|---|---|---|
| **Alda-Vidal *et al.* (2024)** | 1 | Malawi | Non-sewered | Capture | Low | Drought |
| **Bissati *et al.* (2022)** | 2 | Algeria | Mixed | Treatment | Upper-middle | Drought/ Extreme heat |
| **Grimason *et al.* (2000)** | 3 | Malawi | Non-sewered | Capture | Low | Increasing rainfall/Flooding |
| **Hoque *et al.* (1989)** | 4 | Bangladesh | Non-sewered | Capture | Low | Increasing rainfall/Flooding |
| **Jewitt *et al.* (2018)** | 5 | India | Non-sewered | Capture | Lower-middle | Increasing rainfall/Flooding |
| **Kanda *et al.* (2022)** | 6 | Zimbabwe | Non-sewered | Capture | Low | Increasing rainfall/Flooding<br>Drought<br>Severe wind |
| **Marlow *et al.* (2011)** | 7 | Australia | Sewered | Conveyance | High | Drought<br>Increasing rainfall/Flooding |
| **Allouche *et al* (2012)** | 8 | USA | Sewered | Treatment | High | Increasing rainfall/Flooding<br>Severe wind |
| **Sellin *et al.* (1978)** | 9 | United Kingdom | Sewered | Conveyance | High | Increasing rainfall/Flooding |
| **Uddin *et al.* (2013)** | 10 | Bangladesh | Non - Sewered | Capture<br>Containment | Lower-middle | Increasing rainfall/Flooding |
| **Gordon and Hueso (2021)** | 11 | Bangladesh | Non-sewered | Capture<br>Containment | Lower-middle | Increasing rainfall/Flooding<br>Severe wind |
| **Rizk *et al.* (2014)** | 12 | USA | Sewered | Treatment | High | Increasing rainfall/Flooding |
| **Morshed *et al.* (2010)** | 13 | Bangladesh | Non-sewered | Capture<br>Containment | Lower-middle | Increasing rainfall/flooding<br>Sever wind |
| **Takasou *et al.* (2002)** | 14 | Japan | Mixed | Conveyance | High | Increasing rainfall/Flooding |
| **McGill *et al.* (2018)** | 15 | Botswana | Non-sewered | Capture | Upper-middle | Increasing rainfall/Flooding |
| **Purwar *et al.* (2018)** | 16 | Philippines | Non-sewered | Capture | Lower-middle | Increasing rainfall/Flooding<br>Severe wind |
| **Parvin *et al.* (2010)** | 17 | Bangladesh | Non-sewered | Capture<br>Containment | Lower-middle | Increasing rainfall/Flooding |

[9]2024 World Bank classification.

**Table 8: Characteristics of included literature for sanitation**

| Characteristics | No. of documents | | |
|---|---|---|---|
| **Literature type** | | | |
| Journal-published study | 17 | | |
| **Type of evidence** | **Quantitative** | **Qualitative** | |
| Empirical | 4 | - | |
| Reported | - | 13 | |
| **Field Foci** | | | |
| Primarily engineering | 6 | | |
| International development | 11 | | |
| **Climate hazard studied**[a] | | | |
| Drought/ Extreme heat | 5 | | |
| Flooding/increasing rainfall | 15 | | |
| Severe wind | 3 | | |
| Sea level rise | 1 | | |
| **Study classification by income**[b] | **Sewered** | **Non-sewered** | **Mixed**[c] |
| High | 4 | - | 1 |
| Upper-middle | - | 1 | 1 |
| Lower-middle | - | 7 | - |
| Low | - | 2 | - |

[a]The sum of climate hazards studied is greater than number of documents as several documents study multiple climate hazards.
[b]According to World Bank classification for the 2024 fiscal year.
[c]Mixed refers to studies on treatment works where it's unclear if they are part of a sewered or non-sewered system.

### 5.3.2 What is being measured?

Sixteen of the seventeen articles focused on outcomes at one element of the sanitation value chain (**Table 9** and **10**). One case study presented an enabling environment attribute which took a 'project wide' perspective. Other literature which presented operational or enabling environment attributes or adaption actions, gave outcomes which were specific to a particular sanitation system component.

From the 15 remaining articles, 9 of those presented evidence relating to latrines (including their pits) and their ability to capture, flush and contain. Four articles analyse sewers and their ability to convey faecal sludge, wastewater and supernatant. Two articles give attributes or adaptive actions for treatment works.

Across the 17 articles analysed, 33 distinct attributes or adaptation actions were initially identified. As many of these articles reported similar or overlapping attributes or actions, they were consolidated into a final set of 27. These 27 attributes or adaptation actions are listed in **Table 9** and **Table 10** Each attribute or action is mapped to the specific climate change effect it aims to address for resilience-building, as well as to the service continuity outcome it supports. Additionally, each attribute or action is mapped on to the framework in **Figure 1**, infrastructure attributes have been further disaggregated by actor.

**Table 9: Mapping of evidence of attributes and adaption actions against climate change effect and service continuity outcomes for sanitation (1 of 2 – Rainfall and winds)[10]**

| Climate Change Effect | Potential climate extremes | Continuity in capture (and flush) of faecal sludge | Continuity in containment of faecal sludge, supernatant and wastewater | Continuity in emptying faecal sludge, supernatant and wastewater | Continuity in conveyance of faecal sludge, supernatant and wastewater | Continuity of volume, proportion, and level of treatment of faecal sludge, supernatant and wastewater |
|---|---|---|---|---|---|---|
| More intense and prolonged precipitation/ more frequent or intense storms or cyclones | Increased flooding/High-intensity rainfall | (i) Latrine sited at risk-based distance from water body (6) (17) | | | (ii) Infrastructure in high volume change potential soil is designed to tolerate expected movement (8) | (iii) Back up treatment process for untreated effluent that bypasses the system (12) |
| | | (iv) Latrine soffit raised above expected flood level (17) | | | | (v) Increased volume capacity at treatment facility |
| | | (vi) Sanitation technology selected based on climate risk (10) (13) | | | (vii) Material selection considers flexibility requirements to accommodate variations in pressure (8) | (viii) Flood protection around treatment facility (12) |
| | | (ix) Erosion protection installed around latrine soffit (6) | | | | |
| | | (x) Compliance with established design standards (6) | | | (xi) Selection non-corrosive materials (8) | (xii) Plan to facilitate increased flow (12) |
| | | (xiii) Technical knowledge of robust construction (3) | | | | |
| | | (ixv) Local availability of materials required for robust construction(3) | | | | |
| | | (xv) Access to multiple sanitation technologies (17) | | | (xvi) Filtration system added to limit CSO spill and increase suspended solid removal efficiency (14) | |
| | | (xvii) Quality assurance process implemented (3) (4) (5) (6) | | | (xviii) Polymer dosing of WW to maintain/increase flow rates (9) | |
| | More extreme winds | (ixx) Multiple water sources for manual flushing if water has been cut off (16) | | | | |
| | | (xx) Construction of temporary toilets during wet or stormy weather (17) | | | | |
| | | (xxi) Dedicated CR investments allow for robust construction & rapid response and repair following climate hazard (11) | | | | |

[10](n) refers to reference in Table 3.

**Table 10: Mapping of evidence of attributes and adaption actions against climate change effect and service continuity outcomes for sanitation (2 of 2 - other climate effects)**

| Climate Change Effect | Potential climate extremes | Continuity in capture (and flush) of faecal sludge | Continuity in containment of faecal sludge, supernatent and wastewater | Continuity in emptying faecal sludge, supernatent and wastewater | Continuity in conveyance of faecal sludge, supernatent and wastewater | Continuity of volume, proportion, and level of treatment of faecal sludge, supernatent and wastewater |
|---|---|---|---|---|---|---|
| More variable or declining rainfall or run-off | More extended dry periods, increased frequency of occurrence of drought (seasonal and longer term | (xxii) Availability of multiple sanitation technologies during drought season (1) (15)<br>(xxv) Multiple water sources for manual flushing during dry periods (1) | | | (xxiii) Sewer diameter-larger diameter pipes give fewer blockages (7)<br>(xxiv) Sewer material - Concrete and VC pipes have high blockage rate than PVC or PE (7)<br>(xxi) Sewer maintenance and rehabilitation programmes (8) | |
| Sea level rise | Rising groundwater in coastal/low/lying areas | | | | | |
| | Saline intrusion in coastal/low-lying zones | | | | | |
| | High water levels (potentially flooding, erosion, landslides) | | | | | |
| More variable or increasing temperatures | Higher ambient air temperatures | | | | | (xxvii) Select appropriate treatment technique for changing ambient temperature (2) |
| | Hot and cold extremes | | | | | |

(n) refers to article reference number in Table 3.

| | | | | | |
|---|---|---|---|---|---|
| User defined attribute | | Adaption action by users | | Attributes of sanitation infrastructure | |
| Service provider defined attribute | | Adaptation actions by service providers | | Adaption actions by national and subnational governments | |
| Policy | | Financing | | Regulation | |
| Institutions | | | | | |

## 5.4 Hygiene

### 5.4.1 Characteristics of evidence

A systematic review was conducted to identify the original qualitative and quantitative evidence that a given attribute of a hygiene system or adaptation action provides a resilient outcome. This is where the functioning of hygiene services and user experience are continued or uninterrupted during and following a climate event.

Initially, just over 5000 records were identified from searching three databases. On top of this, expert consultation was received which added 244 records. The duplicates were detected and eliminated, leaving nearly 3500 titles and abstracts to be screened. Two hundred and thirty-three of these documents were then assessed for eligibility in the full-text screening, which led to 28 records being included in the review. A list of the articles included in the review are shown in **Table 11** and their characteristics are shown in **Table 12**.

The majority of these articles (n=17) were based in countries in LMICs. This suggests a lack of research in high or upper-middle income countries, which may be due to these countries tending to be less at risk from the effects of extreme weather events, although the frequency and severity of climate hazards may be similar. There were few studies focused on low income countries (n=5), indicating a need for further research in these areas, as they are often most vulnerable to climate extremes.

Over a third of the studies (n=10) were based in evacuation camps in the immediate aftermath of an extreme weather event. The remaining articles mainly focused on relief efforts in the general area, with very few (n=4) focusing on building resilience of hygiene systems to reduce the need for these interventions. This shows that there is less of a focus on underlying facilities, with hygiene interventions prioritised.

Over a third of the articles focused on the impact of flooding (n=10). Most of the other articles (n=7) studied general climate hazards, with the remaining focusing on drought, cyclones, hurricanes and heavy rainfall. This highlights that some articles do not focus on the outcomes of a specific extreme weather event and are more generalised, suggesting the lack of evidence for some system attributes and adaptation actions.

Whilst some studies focused on general hygiene services (n=11), there were none solely dedicated to incontinence, indicating a lack of knowledge in that area. The aspect of the scope that the articles mainly focused on was menstrual hygiene management (MHM) (n=10), followed by handwashing (n=7). Most of the studies were about general hygiene services, which may be less useful for assessing the attributes and adaptation actions of specific hygiene systems studies focusing on one aspect of the scope.

### Table 11: Articles included in analysis for hygiene

| Study | Reference Number | Study Location | Study country classification by income[11] | Aspect of Hygiene Scope | Climate Hazard Studied |
|---|---|---|---|---|---|
| Alhassan et al., 2017 | 1 | Ghana | Lower-middle | All | Flood |
| Ashraf at al., 2024 | 2 | Pakistan | Lower-middle | All | Flood |
| Atuyambe et al., 2011 | 3 | Uganda | Low | Handwashing | Heavy rainfall |
| Bhattacharjee, 2019 | 4 | India | Lower-middle | MHM & Handwashing | Flood |
| Büke, Karabayir, 2024 | 5 | General | N/A | Handwashing | General |
| Dembedza, Chopera, Macheka, 2024 | 6 | Zimbabwe | Low | Handwashing | Cyclone |
| Emont et al., 2017 | 7 | Tuvalu | Lower-middle | Handwashing | Drought |
| Jerin et al., 2023 | 8 | Bangladesh | Lower-middle | MHM | Flood |
| Kativhu et al., 2021 | 9 | Zimbabwe | Low | All | Cyclone |
| Khan, 2022 | 10 | Bangladesh | Lower-middle | MHM | General |
| Kohlitz et al., 2022 | 11 | Indonesia & Timor-Leste | Upper-middle & lower-middle | All | General |
| Krishnan, 2019 | 12 | India | Lower-middle | All | Cyclone & Flood |
| Mitu et al., 2022 | 13 | Bangladesh | Lower-middle | All | |
| Moll et al., 2006 | 14 | South America | N/A | All | Hurricane |
| Pinchoff, Dougherty, Dadi, 2023 | 15 | Niger | Low | Handwashing | Drought |
| Rabbani, Tasneem, Onder, 2024 | 16 | Pakistan | Lower-middle | All | Flood |
| Sadique, Ali, Ali, 2023 | 17 | Pakistan | Lower-middle | MHM | Flood |
| Downing et al., 2021 | 18 | Vanuatu | Lower-middle | MHM | Cyclone |
| Sarkar et al., 2023 | 19 | Bangladesh | Lower-middle | MHM & Handwashing | Drought |
| Shukla, Woc-Colburn, Weatherhead, 2018 | 20 | United States | High | Handwashing | Hurricane |
| Krishnan, Twigg, 2016 | 21 | India | Lower-middle | MHM | Flood |
| Sudhiastiningsih, Agustina, Priadi, 2024 | 22 | Indonesia | Upper-middle | MHM | General |
| Talukdar et al., 2023 | 23 | Bangladesh | Lower-middle | MHM | Drought |
| Tshuma, Belle, Ncube, 2023 | 24 | Zimbabwe | Low | All | Flood |
| Tufail et al., 2023 | 25 | Pakistan & India | Lower-middle | MHM | Flood |
| Umair et al., 2022 | 26 | Pakistan | Lower-middle | All | Flood |
| Wilbur, Poilapa, Morrison, 2022 | 27 | Vanuatu | Lower-middle | All | General |
| Yee et al., 2007 | 28 | United States | High | Handwashing | Hurricane |

[11]2024 World Bank classification.

**Table 12: Characteristics of included literature for hygiene**

| Characteristics | No. of documents |
|---|---|
| **Literature type** | |
| Journal-published study | 28 |
| **Evidence** | |
| Yes | 22 |
| No | 6 |
| **Aspect of scope** | |
| MHM | 10 |
| Handwashing | 7 |
| Incontinence | 0 |
| All | 11 |
| **Climate hazard studied** | |
| Flooding | 10 |
| Drought | 4 |
| Cyclone | 3 |
| Hurricane | 3 |
| Heavy rainfall | 1 |
| General | 7 |
| **Study classification by income**[a] | 2 |
| High | 1 |
| Upper-middle | 17 |
| Lower-middle | 5 |
| Low | 3 |
| General | |
| **Article focus** | |
| Planning for extreme weather | 4 |
| Aid to general area | 14 |
| Evacuation camps | 10 |

[a]According to World Bank classification for the 2024 fiscal year.

## 5.4.2 What is being measured

Much of the literature focuses on the delivery of behaviour change programmes, while there are some indicators for continuity of access across products, infrastructure and cleaning and disposal. There are very few indicators for supply chains. The most common climate change effect that is considered is more intense rainfall and subsequent flooding (**Table 13** and **14**).

**Table 13: Evidence Mapping of evidence of attributes and adaption actions against climate change effect and service continuity outcomes for hygiene (1 of 2 – indicators with evidence)[12]**

| Climate change effect | Potential climate Hazards | Delivery of behaviour change programs, education and hygiene promotion messaging | Supply chains - access to safe, secure and preferred methods of distribution of hygiene products | Continuity of access to safe, secure and preferred type of products | Continuity of access to safe, secure, functional and preferred infrastructure for hygiene practices | Continuity in safe, secure, discrete and preferred services for cleaning and disposal |
|---|---|---|---|---|---|---|
| **More intense and prolonged precipitation/ more frequent or intense storms or cyclones** | Increased flooding/ High-intensity rainfall | Access to education on the pros and cons of MHM products during emergencies (4) | | Access to safe, secure and preferred MHM products (4) (8) (17) | Access to safe and separate facilities for MHM (9) (18) | |
| | | Access to health clubs to reduce the reliance on health workers (9) | | Use of homemade menstrual products (17) | Access to structure to practice MHM close to home (13) | |
| | | Access to educational programs promoting behavioural hygiene changes (9) | MHM products discretely distributed by preferred persons (17) | Receipt of hygiene kits containing preferred MHM essential items (17) (18) (21) (22) | Access to temporary structure to practice MHM when primary structure is unusable (17) | Disposal of menstrual cloth after single use to eliminate the need for washing and drying (4) |
| | | Maps available identify climate hazards in WASH and their impacts on women, men, and individuals with disabilities (9). | Population provided with hygiene kits in lead up to disaster (1) | | Evacuation camps provide privacy screen to practice MHM (21) | |
| | | | Drone technologies used to distribute hygiene materials post-disaster (16) | Receipt of hygiene kits containing preferred materials (9) | Separate bathing units for menstruators to practice MHM (21) | |

[12](n) refers to reference numbers in Table 10.

| Climate change effect | Potential climate Hazards | Delivery of behaviour change programs, education and hygiene promotion messaging | Supply chains - access to safe, secure and preferred methods of distribution of hygiene products | Continuity of access to safe, secure and preferred type of products | Continuity of access to safe, secure, functional and preferred infrastructure for hygiene practices | Continuity in safe, secure, discrete and preferred services for cleaning and disposal |
|---|---|---|---|---|---|---|
| More variable or declining rainfall or run-off | | Access to hygiene education on handwashing, menstrual hygiene, and water management (9) | | | Preferred products for handwashing with soap available at camps (3) | |
| | | Early warning systems implemented about potential hygiene risks (1) | | | | |
| | | | | | Evacuation camps have preferred toilet facilities for women and girls (10) | Utilisation of alternative water sources hygiene purposes during menstruation (19) |
| | More extreme winds | | | Evacuation camp population have access to portable sinks equipped with soap, water and paper towels (28) | | |
| | More extended dry periods, increased frequency of occurrence of drought (seasonal and longer term) | Menstruators receive messaging on h'washg with soap (15)<br><br>Households receive health promotion messages on handwashing with soap (7) | | Access to both soap and alcohol-based hand sanitisers (7) | Access to preferred facilities to practice handwashing (6) | |
| Sea level rise | Rising groundwater in coastal/low-lying areas | | | | | |
| | Saline intrusions in coastal/low-lying areas | | | | | |
| | Higher water levels (potentially flooding, erosion, landslides) | | | | | |
| More variable or increasing temperatures | Higher ambient air temperatures | | | | | |
| | Hot and cold extremes | | | | | |

**Table 14: Mapping of evidence of attributes and adaption actions against climate change effect and service continuity outcomes for hygiene (2 of 2 – indicators with no evidence)[13]**

| Climate change effect | Potential climate extremes | Delivery of behaviour change programs, education and hygiene promotion messaging | Supply chains - access to safe, secure and preferred methods of distribution of hygiene products | Continuity of access to safe, secure and preferred type of products | Continuity of access to safe, secure, functional and preferred infrastructure for hygiene practices | Continuity in safe, secure, discrete and preferred services for cleaning and disposal |
|---|---|---|---|---|---|---|
| **More intense and prolonged precipitation/ more frequent or intense storms or cyclones** | Increased flooding/ High-intensity rainfall | Education on the use and disposal of menstrual products during emergencies (17)<br>Access to safe space for discussing MHM in educational programs (25)<br>Education on the use of unfamiliar MHM materials included in hygiene kits (27)<br>Children's access to education on alcohol-containing disinfectants use (5) | | Women are consulted on their preferences for hygiene kit contents (4)<br>Access to alcohol-based disinfectants when soap is unavailable (5) | | Disposal included in pre-disaster planning for MHM (4) |
| | | Local councils have budget allocations for rural hygiene initiatives (24) | | | | |
| | | Hygiene awareness programs implemented (26) | | Hygiene kits contain incontinence materials (27) | | |
| | More extreme winds | | | Access to proper handwashing with soap, water and alcohol-based hand sanitisers (20) | | |

[13](n) refers to reference numbers in Table 10.

| Climate change effect | Potential climate extremes | Delivery of behaviour change programs, education and hygiene promotion messaging | Supply chains - access to safe, secure and preferred methods of distribution of hygiene products | Continuity of access to safe, secure and preferred type of products | Continuity of access to safe, secure, functional and preferred infrastructure for hygiene practices | Continuity in safe, secure, discrete and preferred services for cleaning and disposal |
|---|---|---|---|---|---|---|
| More variable or declining rainfall or run-off | More extended dry periods, increased frequency of occurrence of drought (seasonal and longer term) | Children's access to education on alcohol-containing disinfectants use (5) | | Access to alcohol-based disinfectants when soap is unavailable (5) | | |
| Sea level rise | Rising groundwater in coastal/low-lying areas | | | | | |
| | Saline intrusions in coastal/low-lying areas | | | | | |
| | Higher water levels (potentially flooding, erosion, landslides) | | | | | |
| More variable or increasing temperatures | Higher ambient air temperatures | | | | | |
| | Hot and cold extremes | | | | | |

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**Legend**

| | |
|---|---|
| | Adaption action by users |
| | Adaption actions by hygiene promoters and supply chain actors |
| | Attributes of water, sanitation, and hygiene infrastructure |
| | Handwashing facility function: Available hygiene materials and disposal facilities |
| | User experience of practicing hygiene behaviours |
| | Adaptation action by national and subnational governments - Policy |
| | Adaptation action by national and subnational governments - Finance |

# 6.0 From evidence to the long list

## 6.1 Status of evidence

Early indications from the WASH resources review suggest that there are a large number of indicators for climate-resilient WASH that have been proposed in sector documents, across all elements of our framework (**Figure 1**). However, the reviews for water supply, sanitation and hygiene highlight that evidence of the links between specific attributes of WASH systems or adaptation actions by key actors and resilient service outcomes or a maintenance of adequate levels of user satisfaction, under climate stressors, is uneven or absent in most cases. We note the following general gaps in the evidence base:

Considering WASH system attributes:

- for well-established networked systems in both water supply and sanitation there is some empirical evidence but (a) much of it is hard to access as it is operational information from utilities; and (b) what is published tends to be modelled rather than observed data;
- for less well-established systems, non-networked systems and in low- and middle-income settings, the evidence base is small and tends to cluster around certain pieces of infrastructure (e.g. handpumps with boreholes, latrines) rather than systems as a whole; and
- for hygiene (and this may reflect a gap in the water supply and sanitation literature as well) there are very few proposed indicators for supply chains and none have a strong basis in evidence.

In terms of the main climate-related events:

- for water supply, drought is by far the most studied hazard, with others somewhat under-represented;
- for sanitation, flooding and intense rainfall is by far the most studied hazard and there is much less on drought and sea level rise although some flooding studies in coastal areas probably include sea level rise effects; and
- for hygiene, the most studied hazard is intense rainfall and subsequent flooding which reflects a bias towards rapid onset climate events with high impact.

Considering outcomes from a user perspective:

- there is some evidence of systematic approaches to collect data on service outcomes (and both JMP and GLAAS have played an important role in many cases) but there is very limited evidence of the use of systematic high-quality methods to assess user experience outcomes;
- key outcomes identified in the water supply review were related to the continuity of supply, and the volume of quality of water supplied;
- for sanitation, key user outcomes varied with the type of infrastructure under consideration. For sewered systems, continuity in conveyance of wastewater and continuity of treatment were well represented. For systems using pits and tanks, continuity of access to the toilet itself was often the outcome of interest. Continuity in road-based emptying and conveyance systems was not well documented; and

- for hygiene, the focus tended to be on the delivery of behaviour change programmes, while there are some indicators for continuity of access across products, infrastructure and cleaning and disposal but almost nothing on supply chains.

The incomplete evidence base is liable to lead to certain biases in the proposition and assessment of potential indicators for consideration in the long list. In particular we might anticipate that measures and indicators associated with the following may dominate:

- attributes or adaptation actions that respond to the most well-understood or commonly documented climate-related events (drought for water supply, flooding and intense rainfall for sanitation);
- attributes or adaptation actions that have already been measured and/or assessed;
- attributes or adaptation actions that could more easily be measured and assessed; and
- attributes or adaptation actions that fall within the technical expertise or knowledge of respondents.

Thus, while the results of the evidence reviews are intended to assist in the evaluation of candidate indicators (the existence or absence of evidence is likely to be a criteria), they cannot be taken as the *only* starting point for the development of the long list of indicators. The review of climate-resilient monitoring resources in WASH and WASH-adjacent sectors provided some candidate indicators to fill the gaps in the evidence base. Other gaps were filled from frameworks in the WASH sector that do not have a specific climate resilience or monitoring focus.

## 6.2 Drawing indicators from evidence to develop the long list

Overall we were able to identify 273 candidate indicators for use in the draft long list, 173 from the review of WASH resources, 3 from the review of WASH-adjacent resources, 17 from the evidence review on water supply, 32 from the evidence review on sanitation (plus a further 9 modified alternates relating to other elements of the sanitation chain) and 39 from the evidence review on hygiene.

The review of WASH and WASH-adjacent resources as a whole provides some useful framing and concepts which we have used to fill gaps in the long list with candidate indicators which have been proposed for which there is limited evidence. We have also been able to include further indicators for areas which are not covered by any of the documentation that we found but still within the agreed scope of the project.

## 6.2 Curation of the long list

The long list is curated and organized so that it can be searched by sector (water supply, sanitation, hygiene), by components of the framework, and by climate hazards. In line with **Table 2** the list can also be sorted by key outcome categories. The hygiene indicators have also been subdivided into those related to hand hygiene, menstrual hygiene management, and incontinence management.

All candidate indicators are tagged with information relating to the source, and data requirements.

# 7.0 Next steps

Inputs are currently sought from the technical working group and through public consultation on the following questions/ issues:

1. **Completeness of the evidence reviews**
    - Are there obvious gaps, resources, papers or evidence that are missing from our reviews (lists of all the resources that we have reviewed are available for reference)?
2. **Completeness of the indicator long list**
    - Does the long list reflect the evidence review findings?
    - Does the long list reflect the agreed scope of the project and align with our working definitions of climate-resilient WASH?
    - What, if any, are major gaps both in terms of thematic areas, and specific indicators?
3. **Focus of the indicator list**
    - With reference to the review of WASH and WASH-adjacent resources, in particular, we note that proposed indicators tend to skew towards rapid onset high impact events rather than slow onset events. Is the balance now corrected by the additional indicators?
    - With reference to the Scoping Document and current definitions of climate resilience, is the long list sufficiently reflective of more ambitious dimensions of resilience?
    - Do we have the right set of candidate indicators regarding system functioning?
    - Amongst the indicators selected, is the balance right between climate specificity, and climate relevance? (As an example, should non-revenue water be included since it is climate relevant even though it also reflects "good" WASH management practices more generally?)
4. **Appropriateness of user experience indicators for climate resilience**
    - A specific challenge arises around indicators on user experience of climate resilience. This can be because of the inherent subjectivity of user experiences, as well as the accuracy (or lack thereof) in the ways that users remember and report events. There may be better recall for significant events; larger events or disasters may result in more accurate user recall compared to smaller, routine incidents. What are some of the ways in which these challenges can be addressed?
5. **Alignment with other indicator development processes**
    - Is the list useful and relevant and aligned to ongoing work towards indicator development for the Global Goal for Adaptation?

# Annex 1: Methods and PRISMA - Water supply

## A1.1 Review question

To what extent do technical, operational and enabling environment attributes affect the system functioning and user experience of drinking water supply during or following climate variability and extreme weather events?

## A1.2 Methodology

The protocol for the umbrella review was developed in accordance with the resilience framework guiding this project. All review papers with evidence that an adaptation action or a system attribute had affected the functioning of a water supply or user experience during or after a climate-related event, written in English, French, Spanish and Portuguese were eligible. No restrictions were placed on the date of publication or location of primary studies included in the review. Both systematic and non-systematic literature reviews were included.

## A1.3 Screening and selection

Two databases – Web of Science and Scopus – were searched using the following search terms:

*TI=(water AND climate) OR TI=(water AND extreme AND weather)*

*Article type = reviews*

After screening titles, abstracts and full text of each eligible review, data was extracted on their settings, climate hazards, adaptation actions, attributes and reported outcomes.

Following this, the primary studies in each eligible review were screened. Evidence on qualitative and quantitative evidence of associations between outcomes and actions or attributes was extracted using a pre-set data extraction form. Candidate indicators will be identified based on these attributes and actions.

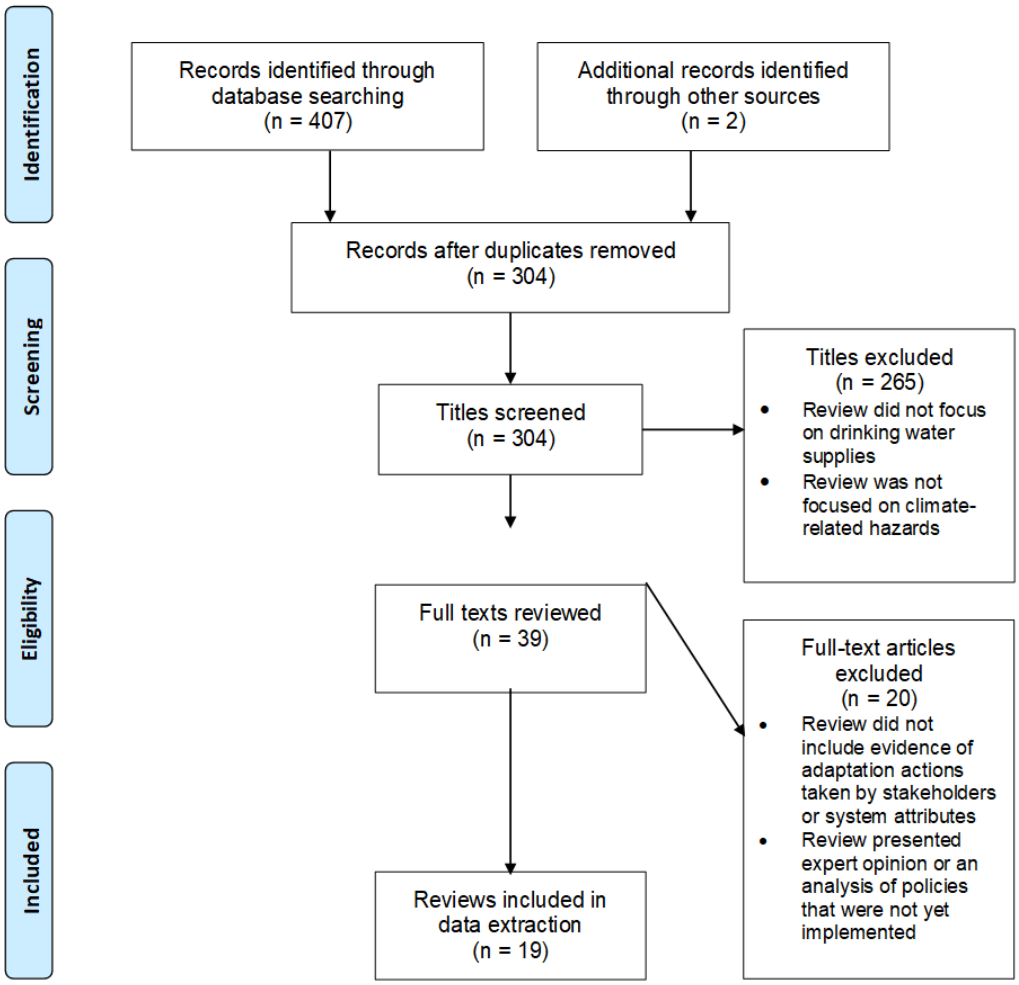


**Figure A1.1 PRISMA flow diagram of the umbrella review on evidence on water supply**

# Annex 2: Methods and PRISMA - Sanitation

## A2.1 Review question

To what extent do technical, operational, and enabling environment attributes and adaptation actions impact user experience and system functioning of sanitation systems during and following climate hazards?

## A2.2 Materials and Methods

This study follows the standard systematic review methodology, in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). This process was adopted to identify original qualitative or quantitative evidence that a given attribute of a sanitation system provides a resilient outcome, i.e. the service and user experience is continual or minimally interrupted during and following a climate event.

This review was restricted to studies available in English, whether originally written in the language or translated, and did not impose any restrictions on the publication date of the literature considered. Evidence was collected from peer-revied journal articles, published conference proceedings and grey literature.

To search for peer-reviewed literature, a search strategy was developed. This was based on a combination of three primary concepts, climate change, sanitation systems and service continuity. The search terms used can be found in Table A2.1.

**Table A2.1 - Electronic Database Search Strategy[a]**

| *Ref* | *Concept* | *Search terms* | |
|---|---|---|---|
| *A*<br>*(1 OR 2)* | Climate change | 1 | (Extreme* OR intense* OR declin* OR prolong* OR increas* OR variab* OR heavy OR decreas* OR rise*) w/3 (rain* OR precipitation OR "dry period" OR snow OR storm OR wind* OR "sea-level" or heat or cold OR temperature OR cyclone* OR typhoon* OR hurricane) |
| | | 2 | Drought or flood or clima* |
| *B*<br>*(3 OR 4 OR 5 OR 6)* | Sanitation system | 3 | toilet* OR latrine* OR sanita* OR ecosan OR "septic tank" |
| | | 4 | (feces OR faeces OR fecal OR faecal OR excre* OR waste OR sludge OR wastewater OR "waste water" ) W/3 ( dispos* OR manag* OR service OR treat* OR desludge* OR empt* OR transport* OR pit OR pits OR *pits) |
| | | 5 | sewage OR sewer* OR sewerage OR wastewater OR "waste water" |
| | | 6 | open W/1 defecation OR sanitation |
| *C* | Continuity of service and user experience | 7 | (contin* OR maintain* OR increas* OR decreas* OR interrupt* OR consistent OR inclusive OR equal* OR equit* OR reliable OR level) w/3 (access Or provi* OR availab* OR us* OR afford* OR connect* OR allocat*) |

[a]This table presents the search strategy used for the Scopus database. The proximity operators have been adapted in compliance with the conventions of the respective database

The search was conducted in July 2024 in databases: Web of science, CB abstracts, Medline, Global Health, and Scopus.

## A2.3 Screening and selection

A systematic search the literature databases yielded almost 4000 article returns, after uploading to Rayyan QCRI webtool, duplicates were removed, identifying 3461 eligible for title screening. The titles, abstracts, and then full texts were reviewed against the exclusion criteria by two independent authors (JW & MW) followed by a third reviewer (BE) who reviewed any disagreements. Identification, screening and selection process is described in **Figure A.2**.

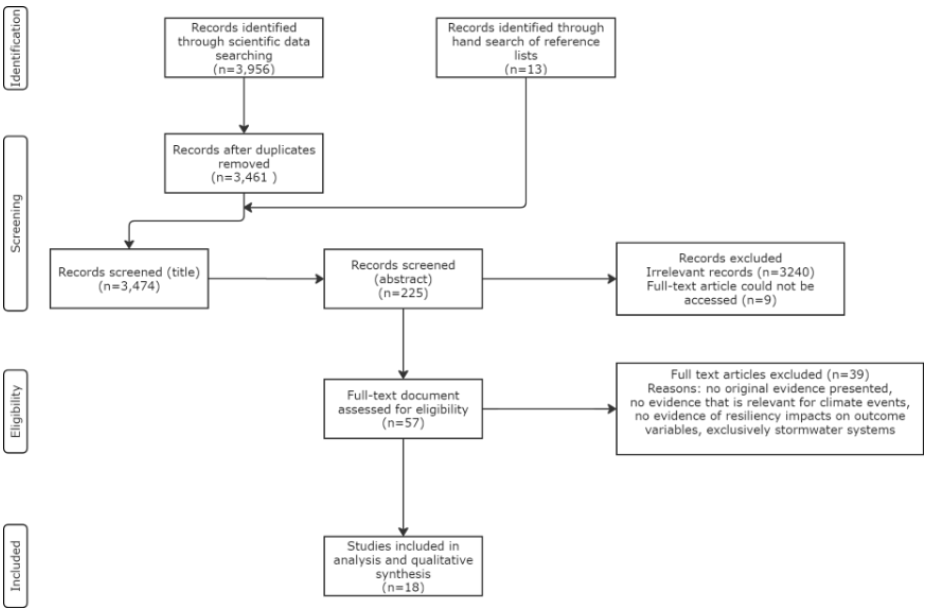


**Figure A.2 - Flow diagram summarising the screening and selection process**

Thirteen articles were identified through hand searching reference lists of included articles. Gray literature searching and expert consultation gave no studies eligible for inclusion. 495 duplicate records were removed. From the remaining 3478 articles only 57 were selected for full-text screening, 8 of these papers could not be accessed so were not included in the final analysis. Following the full-text screening, 17 articles were included in the final analysis. Most of the excluded articles were omitted based on the exclusion criteria outlined in **Figure A.2**.

# Annex 3: Methods and PRISMA - Hygiene

## A3.1 Review questions

Primary review question: What is the evidence that infrastructure, operational and enabling environment attributes and adaptation actions impact user experience and system functionality of hygiene systems during and following climate extremes?

Secondary review question: Which infrastructure, operational, and enabling environment attributes or adaptation actions are most likely to influence user experience and system functionality of hygiene systems during and after climate extremes?

The secondary review question was introduced as it was anticipated that the evidence in the literature addressing the primary review question would be limited and/or of poor quality. During the full-text screening stage, the texts were initially analysed in relation to the primary review question, then the secondary review question and it was noted whether there was evidence of the system attribute or adaptation action.

## A3.2 Materials and Methods

A systematic review was conducted in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) to identify the original qualitative and quantitative evidence that a given attribute of a hygiene system or adaptation action provides a resilient outcome. This is where the functioning of hygiene services and user experience are continued or uninterrupted during and following a climate event.

Table A3.1 shows the search terms used in the Web of Science database. These search terms have also been adapted to be used in compliance with other databases by changing the proximity operators. They are based on the key aspects of the scope which are climate change, handwashing, menstrual health management (MHM) and incontinence. The search string will include topic A, and one of the terms in topic B.

**Table A3.1 – Electronic Database Search Strategy for Hygiene**

| Search Topic REF | Search Topic | Search terms (Web of science) |
|---|---|---|
| A<br><br>1 | Climate change | 1 TS=((Extreme* OR intense* OR declin* OR prolong* OR increas* OR variab* OR heavy OR decreas* OR rise* OR chang* OR hazard OR disrupt* OR impact* OR emergenc* Or sustain*) NEAR/3 (rain* OR precipitation OR "dry period" OR snow OR storm OR wind* OR "sea-level" OR heat OR cold OR temperature OR cyclone* OR typhoon* OR hurricane OR flood OR drought OR clima*)) |
| B<br><br>2 OR 3 OR 4 | Hygiene | 2 TS=(("Hygien*" ) AND ( behavi?r* OR management OR personal OR hand OR practic* OR intervention* OR promotion OR education OR compliance OR product* OR messaging OR communication OR soap OR saniti?e OR "alcohol gel*" OR "alcohol wipe*" OR "alcohol rub" OR antiseptic* OR decontaminat* |

| | | |
|---|---|---|
| | | OR clean OR sterili?e OR wash OR ((water OR freshwater) NEAR/3 (suppl* OR consumpt* OR security OR availab* OR poverty OR stress))))<br>3 TS=((Menstrua* OR menses OR menarche OR catamenia))<br>4 TS=(Incontinen* OR "bladder control" OR "urinary leakage" OR "bowel control") |

Search string: A AND B

The search was conducted in December 2024 in databases: Web of science, Scopus, Ovid.

## A3.3 Screening and selection

Following a systematic literature search just over 5000 records were identified. On top of this, expert consultation was received which added 244 records. These were uploaded to the Rayyan QCRI webtool which detected and eliminated the duplicates, leaving nearly 3500 titles and abstracts to be screened. 233 of these documents were then assessed for eligibility in the full-text screening against the exclusion criteria in SysRev, which led to 28 records being included in the review. **Figure A.3** summarises the process that was undertaken to reach this outcome.

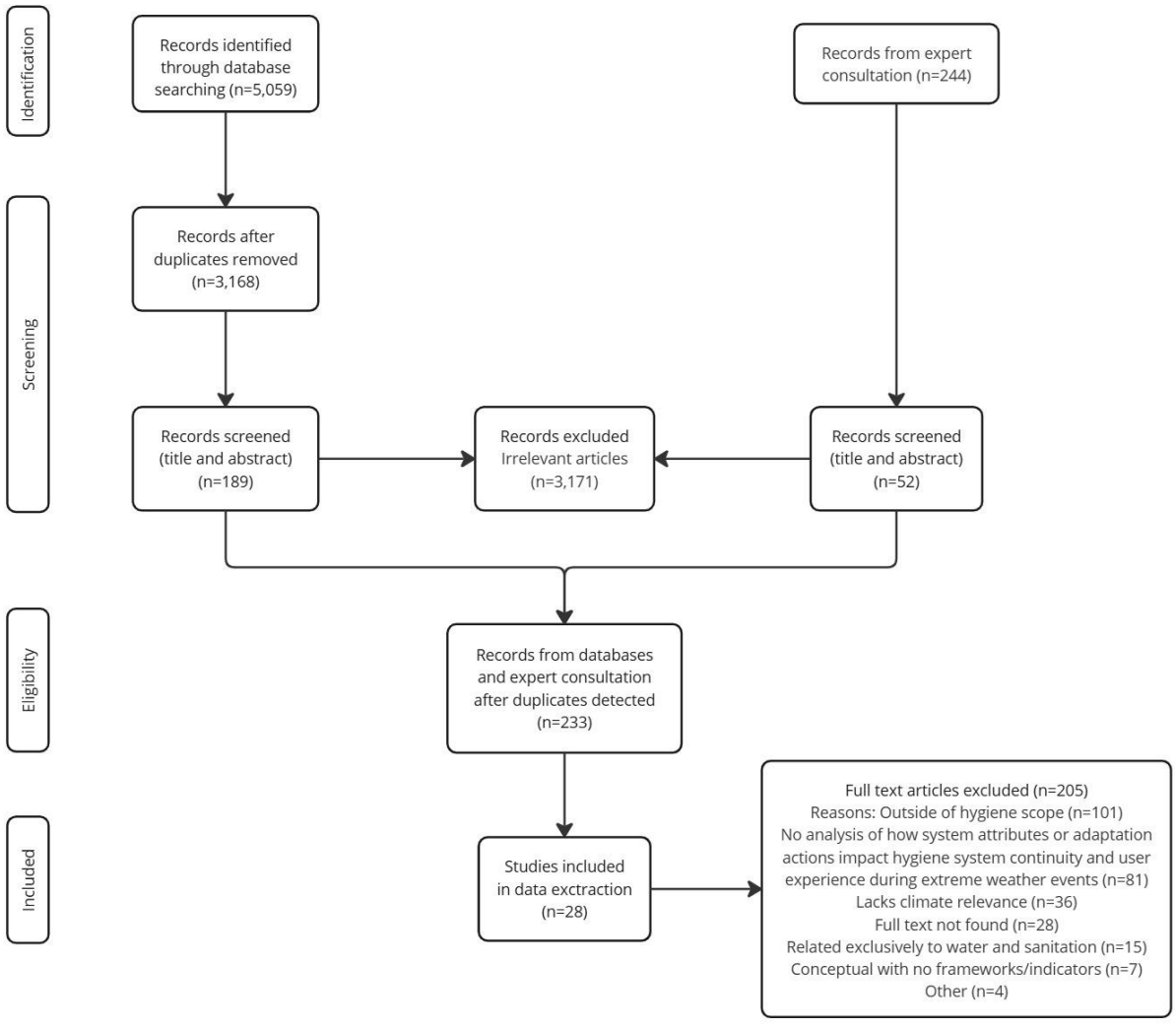


**Figure A.3 – flow diagram summarising the screening and selection process**