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Considering climate change in urban sanitation

Conceptual approaches and practical implications

SNV

UTS Institute for Sustainable Futures

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Photo (cover): Rupnagar Mirpur slum area in Dhaka, Bangladesh (©SNV/ Aidan Dockery)

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Introduction

This paper presents a comprehensive conceptualisation of how climate change could be considered in urban sanitation policy and programming.

Given the urban sanitation crisis facing many cities in developing countries, consideration of climate change can seem like an unwanted distraction from the immediate problems at hand (Bartram, et al., 2017). Climate hazards are often perceived as secondary to the urgency of establishing functioning urban sanitation systems. However, many of the deficiencies in sanitation services also limit cities' resilience to disasters and present climate variability (the "adaptation deficit"), as well as to more extensive and long-term climate change (World Bank, 2010).

As global warming continues to exacerbate weather variability and push climate extremes to new limits, it is likely that climate hazards will increasingly require proactive planning for sustainable sanitation services. In addition, if we hope to improve sanitation services, it is vital that today's investments in systems and service models must remain appropriate in a changing climate, and not tie up future funding in avoidable repairs and replacements. The global drive and funding to address climate change also provides an opportunity to push improvements in the resilience and sustainability of sanitation systems. Moreover, recognition of the interconnections between sanitation and other urban systems can help prioritise sanitation improvements that achieve multiple goals.

Approach and analytical framework

We took three steps to develop the concepts described in this paper. Firstly, we undertook a brief review of the existing (limited) literature that relates climate change to the urban sanitation sector. Secondly, we drew on this literature and previous work led by ISF-UTS on climate change and water, sanitation and hygiene (WASH) to consider how these concepts could usefully be applied to urban sanitation. Thirdly, we distilled this work guided by two questions: What conditions does climate change create that influence urban sanitation services? And what are the implications for policy and programming?

In the global environmental and climate change arena, risk-hazard,[1] resilience and vulnerability are the three common approaches to informing research, practice and policy making (Janssen, et al., 2006; Eakin, et al., 2009). Each approach conceptualises how climate change affects systems differently. Consequently, each emphasises different response strategies with respect to technology, the natural environment and social welfare. We considered the relevance of these approaches for urban sanitation, drawing and building on research by Kohlitz, et al. (2017, 2018) that interpreted these approaches for rural water services.

To assess the implications of these concepts for urban sanitation policy and programmes, we have drawn on existing frameworks for building the enabling environment for urban sanitation services (Lüthi, et al., 2011; World Bank, 2017; WWP-UN, 2017). From these frameworks we identified seven components to categorise the policy and programme changes needed to create an enabling environment for urban sanitation that considers climate change: (i) planning and decision making; (ii) institutional arrangements; (iii) sustainable and responsive financing; (iv) infrastructure and service provision; (v) user engagement and awareness (vi); water cycle, environment and public health; and (vii) monitoring evaluation and learning.

[1] Also known as the adaptation approach.

Existing literature

The literature on climate impacts on sanitation is extremely sparse, particularly for developing countries, despite the potentially significant consequences (Calow, et al., 2011; Howard, et al., 2016). Our review found that the literature to date has focussed on physical and technological aspects, to the exclusion of consequences for the social and institutional systems that are critical for urban sanitation service delivery. We also found limited consideration of the opportunities that climate change could offer. Below we provide an overview of the existing literature and the gaps identified.

Much of the existing literature focuses on the physical impacts of climate hazards on sanitation technologies and making technological adaptations (Kohlitz, et al., 2017), reflecting the WASH sector's general tendency to view technology as a solution to environmental problems (Mehta and Movik, 2014; Carrard and Willetts, 2017).

This literature identified the following hazards and impacts of climate change and their implications on technological adaptations.

- Flooding and increasing precipitation are perhaps the most commonly reported climatic hazard for urban sanitation. In particular, they note the public health risk caused by the spreading of faecal matter from flooded pits and tanks and potential damage to wastewater treatment plants (WHO, 2011; Sherpa, et al., 2014; Cissé, et al., 2016; Howard, et al., 2016).

- Drier conditions driven by climate change were also reported to be problematic with water shortages restricting functionality and contributing to corrosion of piped sewers for water-based sanitation. Water shortages can also lead to higher pollution concentrations in wastewater and reduce the capacity of receiving waterbodies to dilute discharged wastewater (Howard, et al., 2010; WHO, 2011; Vo, et al., 2014).

- Sea-level rise is expected to affect treatment plants, which are often located in low-lying or coastal areas and are subject to inundation, flooding, storm surge, erosion and saltwater intrusion (KWL, 2008). This may result in lower treatment efficiency, higher risk of bypasses and damage to treatment processes from salinity (Flood and Cahoon, 2011).

- Temperature rise has been noted to potentially improve wastewater treatment processes (warmer temperatures can accelerate biological treatment processes) and while treatment plants can typically operate over a range of temperatures, if temperatures exceed or drop below this range, the biological processes will be affected (Vo, et al., 2014). Higher temperatures could increase corrosion of sewers as well as lead to increased evaporation or fermentation in faecal sludge treatment, affecting performance or creating offensive odours (KWL, 2008).

- The intensity or frequency of cyclones and other storms could increase, damaging sanitation infrastructure such as latrine superstructures, pipes and treatment plants or power supplies necessary for piped sewer systems and wastewater treatment plants (Luh, et al., 2017).

The literature also highlights two areas in which urban sanitation contributes to climate change.

- The greenhouse gas (GHG) emissions of the faecal waste itself are influenced by how it is handled and stored. GHGs can be produced and emitted from wastewater at many stages between source and final disposal, and emissions from developing countries are generally higher than in developed countries (IPCC, 2007). On-site options also contribute to emissions, with domestic septic tanks accounting for 1.5% of an individual's annual carbon footprint in the United States (Truhlar, et al., 2016). Septic tanks that are not regularly emptied have an increased risk of methane release (IPCC 2006).

- Sanitation infrastructure, particularly the pumps for large centralised systems and mechanised treatment processes, can be energy intensive and emit greenhouse gases (Carrard and Willetts, 2017).

However, at the same time, climate change could offer some opportunities, including motivation to mobilise more resources for improving WASH services (Howard, et al., 2010) and greater public acceptance of and demand for wastewater or sludge reuse (Vo, et al., 2014).

Social and institutional aspects have been missing from the literature to date.

Assessments of risks and hazards related to infrastructure, which dominate the literature, represent one aspect of the challenges associated with climate change. A broader consideration of the physical risks and hazards would recognise the social systems connected to service use and management and the interactions between social and bio-physical systems (Kohlitz, et al., 2018). Similarly, urban sanitation is more than infrastructure or hardware.

The delivery and access to sanitation services must consider, for example, the 'software' of services, behaviour change, public awareness, governance, monitoring and regulation, as well as the roles of stakeholders — institutions, public and private service providers, communities and users. By taking a more holistic perspective on improving citywide sanitation services for all, this paper hopes to fill the gap in discussions of how urban sanitation services can be best developed and sustained in the context of climate change.

Conceptualisations of climate impacts

The implications of climate change for society are wide-ranging and can be framed in different ways (Kohlitz, et al., 2017). In this section, we describe how climate change could alter the conditions of urban sanitation access and service delivery from three perspectives: risk-hazard, resilience and vulnerability (Figure 1). These perspectives are then applied to analyse the possible climate impacts for the urban sanitation sector.

Risk-hazard: Increased risk to systems

Theory

Perhaps the most common perspective on the impacts of climate change is the risk-hazard approach, which interprets the threat of climate change in terms of the physical risk that climate hazards pose to systems — in this case, urban sanitation (Eakin and Luers, 2006). Depending on the region of the world, climate change projections indicate a range of future changes to precipitation, temperatures, extreme weather events, and sea level, which create physical hazards for urban sanitation such as flooding, drought, inundation, erosion and rising water tables (Sherpa, et al., 2014; Luh, et al., 2017). The risk that these climate hazards pose for urban sanitation is a function of the likelihood that the sanitation system is exposed to the hazard and the severity of damage if the system is exposed. In developing adaptations, the literature defines hazards to include both shocks (acute or short-term external changes that have substantial impact on people or systems) and stressors (long-term or chronic trends or pressures that undermine the stability of a system) (Choularton, et al., 2015).

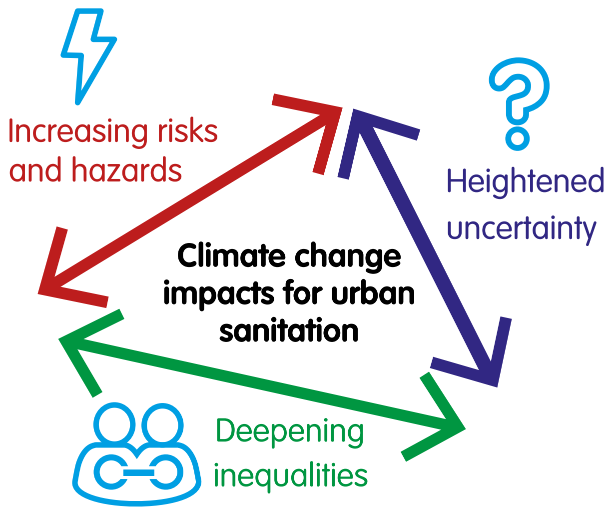

Figure 1 Perspectives on climate change impacts

It is difficult to predict with accuracy how climate hazards will change for each city: the effects will not be uniform across regions, and diverse changes in many extreme weather and climate events are expected (Figure 2). Nevertheless, it is expected that the frequency and intensity of extreme rainfall events will increase, particularly in mid-latitude and tropical regions. In many subtropical and mid-latitude dry regions, however, mean precipitation will likely decrease.

Very likely, the frequency and duration of heat waves will increase, as will the intensity or duration of droughts. In general, the contrast between wet and dry seasons will be amplified. It is also more likely that cyclones will become more intense in the North Pacific and North Atlantic oceans, and the incidence of extremely high sea level will rise (IPCC, 2014).

Implications for urban sanitation

Viewing climate change consequences for the urban sanitation sector through this perspective involves identifying the hazards that create the highest level of risk for sanitation service delivery and developing control measures to reduce risk. Climate change–driven hazards can disrupt the functionality of urban

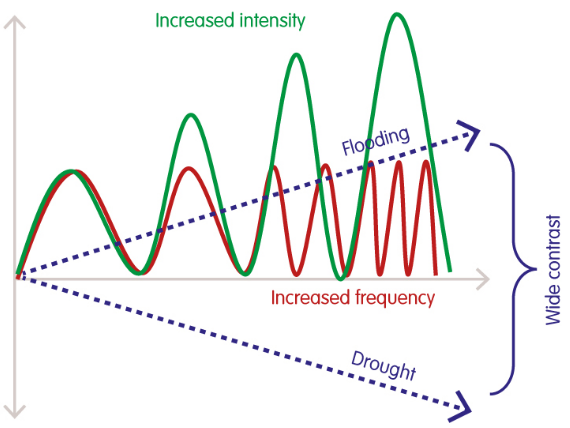

Figure 2 Diverse changes to extreme events

both public health and the environment (Howard and Bartram, 2010; Oates, et al., 2014; Howard, et al., 2016). This would exacerbate the existing problems caused by unsafely managed sanitation — the discharge of untreated faecal waste to the environment and living areas (Robb, et al., 2017). Such risks become more evident in severe climate events, including the frequent outbreaks of sanitation-related disease following disasters, and can persist well after the climate event has ended; one example is the cholera outbreak in Haiti in 2010 (Cravioto, 2011).

sanitation services in many ways: damaging or destroying sanitation infrastructure itself (toilets, pumps, treatment, emptying trucks) or the services on which it depends (drains, water supply, roads, electricity), reducing the functionality or accessibility of sanitation infrastructure. The results would threaten

Predicting the flow-on effects of disruption in urban sanitation is particularly complex because of the numerous steps in the service chain, the non-homogeneity of sanitation systems across a city and the dynamic interconnected flow paths, where changes in behaviour, technology or operation of one part ripples across the urban environment. This complexity is evident in Figure 3, which illustrates the multiple effects of flooding (as one climate change

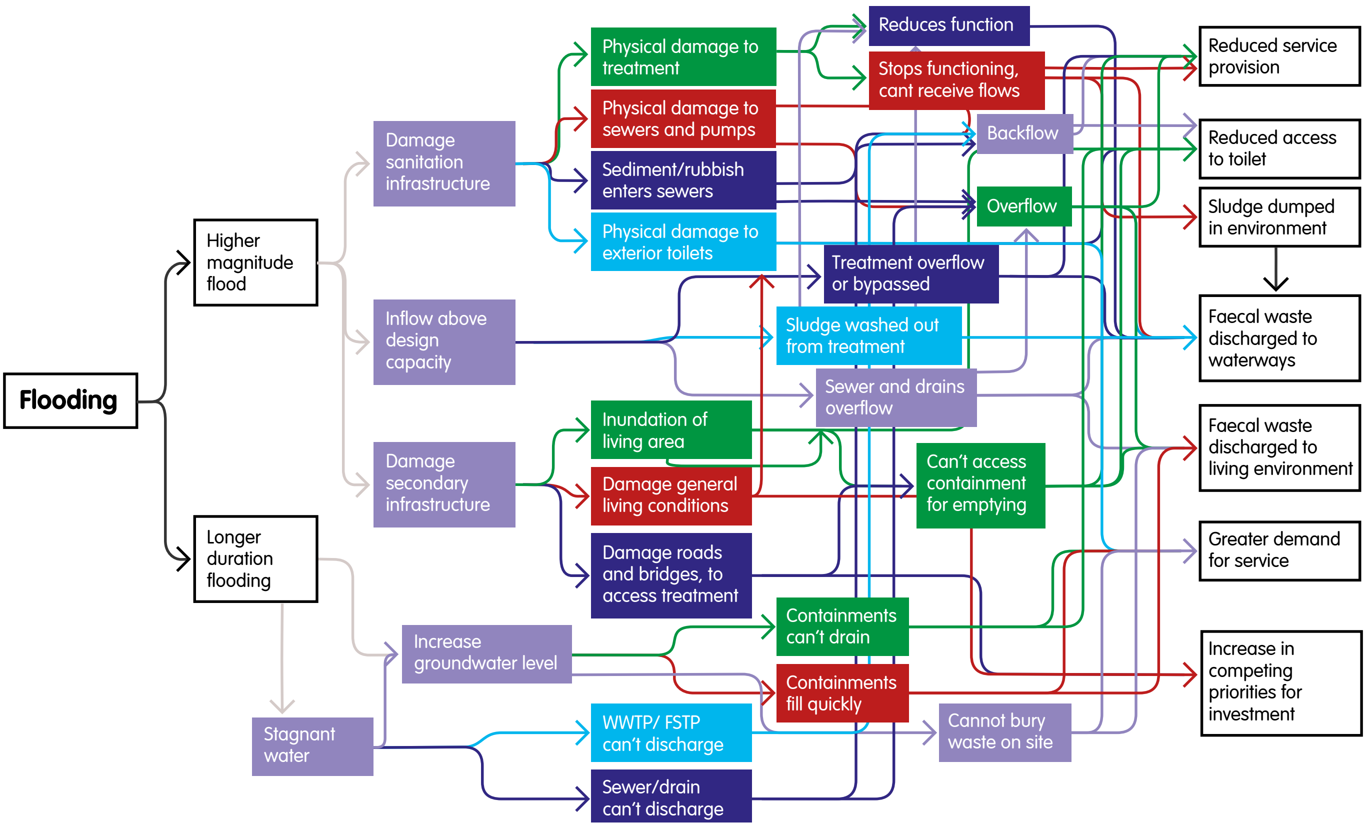

Figure 3 Systems diagramme of effects of flooding on urban sanitation services

hazard) on sanitation infrastructure. This systems diagramme follows effects across technical, physical and social systems. Although these interconnections are complex, common outcomes include a greater demand for services, a simultaneous reduction in service provision, and the need for alternative sanitation options even as competition for investments increases. In addition, the diagram shows the multiple pathways by which pollution of waterways and the living environment will worsen, increasing the risk of exposure to pathogens.

Resilience: Heightened uncertainty

Theory

Another perspective, known as the resilience approach, emphasises the uncertainty or unpredictability that climate change creates for society and nature (Folke, 2006). Part of this uncertainty comes from difficulty in predicting how regional climates will change. However, an even larger uncertainty comes from how society will react to changes in the climate and environment and how these changes interact with other forces (e.g., urbanisation and population growth) to create cascading, emergent and ever-evolving outcomes (Dessai and Hulme, 2004). Because of the high level of uncertainty, some outcomes in the urban sanitation sector may be impossible to predict and therefore cannot be precisely planned for. Conventional risk management strategies will fail because they are predicated on knowing what will happen. The resilience approach therefore aims to address uncertainty by developing a high tolerance for surprises, variability and volatility (Eakin, et al., 2009).

Implications for urban sanitation

Uncertainty is one reason climate change has not been fully considered in the urban sanitation sector. The variable predictions of hazards, the unknown consequences for urban sanitation and uncertainty about the risks have discouraged the WASH sector from exploring climate change adaptations.

Uncertainty can also prevent service users and service providers from investing in improvements (e.g., building toilets) that could be damaged by the next extreme storm.

Supporting sanitation access under increasing uncertainty requires flexibility, adaptiveness and an understanding of urban sanitation system dynamics. However, many urban sanitation systems cannot operate under a range of conditions. Sewers, for example, may not be designed to handle both increased wet weather and water restrictions leading to overflows or sedimentation and fouling. Similarly, centralised sewerage systems may not operate if one link in the service chain — a pump, a sewer pipe — is broken. A treatment plant may be designed without bypasses to allow high flow by-pass or flexible operation when one part is damaged or may be dependent on other systems and services — roads or electricity. Or users may have only private toilets and no access to public toilets, or only one service operator can empty pits and tanks.

Being **adaptable** to uncertain conditions is the key to resilience. It requires **continual learning** and corresponding adjustments to changing conditions, which is far from the reality of management of urban sanitation services in many cities today. Poor understanding of a city's sanitation system, along with a lack of monitoring and warning or response mechanisms, limits the ability of service providers and the public to prepare for or adapt to change. Flow monitoring, for example, could trigger an alert to fix pumps or warn the public of sewer overflows. Many cities lack up-to-date plans, asset registers of sanitation infrastructure and services, and learning processes to adapt management to changes in system performance. Often, sanitation operators or managers are not involved in the system design or investment decisions; that limits their knowledge of the capacity of the system to withstand hazards or how to adapt the system to changing conditions. Uncertainty is also heightened by the interconnected and dynamic nature of urban sanitation: operators may be unable to anticipate consequences for environmental and social systems or see how changes in those systems will affect sanitation.

Vulnerability: Deepening inequalities

Theory

A third perspective, the vulnerability approach, begins with the premise that climate change does not affect everyone equally (Miller, et al., 2010). Some people are more likely to be exposed to climate hazards, suffer greater harm when exposed to hazards, or have less capacity to take action to maintain their well-being when faced with climate-related hazards. Often, discriminatory socio-political structures and institutions are the reason that some people are differentially affected by climate hazards. For example, the poor are often driven to live on marginal land more prone to flooding and have fewer resources to handle inundation of their homes. Furthermore, climate change has potential to exacerbate poverty and inequality (Leichenko and Silva, 2014). The vulnerability approach often sees climate change through a social justice lens and seeks to empower the most disadvantaged groups to pursue their development goals and meet their needs in the face of climate shocks and stresses. Disadvantaged groups that have better access to and control over resources, and power to influence decision-making processes, are better able to adapt to climate disturbances (Burton, et al., 2002).

Implications for urban sanitation

Climate change will likely affect sanitation access most acutely for traditionally vulnerable groups (OHCHR, n.d.). Low-income households or people living in informal settlements often reside on marginal land more prone to climate hazards and are more exposed to the health risks of poor sanitation and polluted water. In addition, informal or low-income settlements often have inadequate basic water, sanitation and drainage systems that are more likely to be damaged or create increased risk compared with more robust systems. Unimproved toilets, for example, are easily damaged, pathogens can wash out from uncontained pits, and leaking containment or drains can increase pollution of shallow wells. Marginalised groups, including women, ethnic minorities, the elderly and people with disabilities, often have greater difficulty accessing sanitation in challenging conditions and fewer resources for adapting to climate change. In addition, they may be less likely to receive information that would help them understand and prepare for climate hazards. They also often have relatively less power to influence decision-making processes about how government and communities should allocate resources to protect society from climate change risks. Moreover, the costs of recovering from natural disasters may divert resources from efforts to address inequality in basic services for vulnerable communities.

Implications for policy and programming

The above perspectives on risk-hazard, resilience and vulnerability have informed the following principles to guide the development of urban sanitation systems that are responsive to climate change.

Optimised and robust hardware to sustain shocks. Consider the robustness of new hardware to the range of predicted climate hazards but also ensure that existing infrastructure operates at optimal capacity. Understanding the current capacity shortfalls and service chain vulnerabilities helps prioritise improvements to system robustness.

Flexibility and diversified risk. Provide alternative options and operational strategies for infrastructure and services to reduce reliance on single systems. Give users more than one option to access sanitation (e.g., alternative systems, services or financing) and design services for multiple or modular operational. Shared management and responsibility can diversify knowledge and improve ability to respond.

Adaptive management to withstand disturbances. Adaptiveness is developed through continual learning and adjustments to changing conditions. Continual learning places more importance on monitoring processes and warning systems to understand how the changing climate is affecting urban sanitation services, its users and the environment.

Raised awareness and knowledge to minimise risk. Stakeholders can take better preventative or adaptive action if they are prepared for climate hazards and uncertainty by building awareness of the risks and knowledge of how to adapt and respond prior to extreme weather events. Real-time awareness, through monitoring and warning systems, can inform users, operators, government, service providers and the public about immediate risks and ongoing changes.

Optimised and robust hardware to sustain shocks. Consideration of system dynamics. Urban sanitation systems are dynamic and complex, involving multiple steps in the sanitation service chain, service configuration and alternative flow paths. Examine all parts of the chain to consider how services can be sustained if one component (e.g., a pump or truck) fails because of climate hazards. Understanding the interconnected and dynamic nature of sanitation systems within the broader urban environment is essential to identifying cross-cutting risks and coordinating preparation and response with other sectors and services.

Attention to distributional effects on equity. Proactive attention is needed to ensure that efforts to improve the sustainability of sanitation services in a time of climate change are equitable. Interventions should explicitly focus on those who are most likely to be affected (and least able to cope with and adapt to changes). Prioritise the needs of disadvantaged groups, including women, and encourage their inclusion in decision-making processes.

Those principles then need to be incorporated into sanitation policy and planning to make urban sanitation systems more resilient to climate change, through both improvements to the existing system and new investments. Delivering sanitation in an era

Seven pillars for sanitation policy and planning responses to climate change

1. Planning and decision making
2. Institutional arrangements
3. Sustainable and responsive financing
4. Infrastructure and service provision
5. User engagement and awareness
6. Water cycle, environment and public health
7. Monitoring, evaluation and learning

of climate change requires services to be sustainable under evolving, uncertain conditions and that climate change adaptation is mainstreamed in urban sanitation policy and planning.

Application of the principles must consider both the biophysical system (e.g., infrastructure, environment) and the social system (e.g., community, politics and institutions). Seven pillars form a holistic framework for assessing how urban sanitation policy and programmes can be developed to better consider climate change. These pillars have been drawn from urban sanitation literature on planning (Luthi, et al., 2011), creating an enabling environment (WWAP, 2017), sustaining services (World Bank, 2017) and poor-inclusive sanitation (Hawkins, et al., 2013).

Considering together the conditions created by climate change, the principles for responding to climate change and the urban sanitation pillars (Figure 4), we have identified implications and suggested actions for policy and programming, detailed below.

1 Planning and decision making

Build climate change literacy. Support the translation and sharing of climate change data and assessments to raise the awareness of sanitation planners and decision makers about climate change hazards, the different conceptualisations of consequences (risk-hazard, resilience and vulnerability) and options for responding. In particular, raise awareness about the likelihood that climate change will disproportionally affect some social groups and how to assess, plan for and prioritise the different needs of vulnerable groups.

Plan for varied climate scenarios. Planning must consider scenarios and responses that cover the breadth and variability of specific risks. For example, plans must accommodate a full range of conditions, from flooding to drought to frequent or prolonged extreme events. Adaptive planning includes short- and long-term actions and allows for dynamic adaption of the plan over time to suit how the future climate actually unfolds (Haasnoot, et al., 2013).

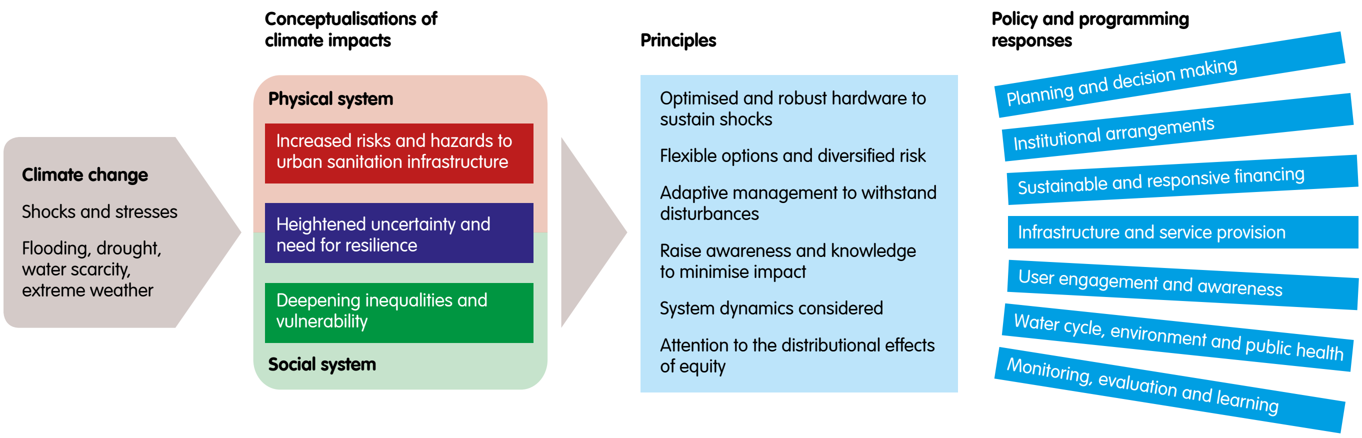

Figure 4 Conditions, principles and pillars for integrating climate change in urban sanitation

Make climate resilience an objective in decision making. Resilience should be explicitly considered in decisions about infrastructure investment in order to consider solutions that promote flexibility and adaptiveness. For example, in multi-criteria assessments, include a component that assesses whether the proposed infrastructure, service or approach is flexible enough for the breadth of future climate conditions and adaptable to uncertainty. Decision making must also prioritise sometimes competing objectives of resilience and risk management, such as flexible versus robust services (see Infrastructure and service provisions below).

Integrate sanitation into the broader urban context. Urban areas in developing countries face many stressors linked to climate change (e.g., urbanisation, population growth, solid waste management). Because these stressors are often interconnected, planning for climate change needs to be integrated within urban planning more generally. For example, sanitation infrastructure planners should consider future plans for water supply (areas to be served, source of supply, water security, water recycling) and flood management (likelihood and level of flood risk can inform siting or prioritization of sanitation investment).

Prioritise infrastructure options that meet immediate needs and can achieve long-term sustainability. Efforts to address climate change effects on sanitation must find balance between meeting the basic necessity of providing access today and anticipating issues that will unfold over many years (e.g., sea-level rise). Given funding shortfalls, focus should be on no- or low-regret solutions that are suitable to all future climate and scenarios yet meet today’s needs, particularly for vulnerable groups (Butterworth and Guendel, 2012). For example, prioritising access to improved sanitation options that also address climate priorities – water efficiency or flood resilience. Another option is to prioritise sanitation infrastructure and services that can be more easily adapted to changing climate conditions, such as distributed systems that are modular and can be interlinked.

2 Institutional and management arrangements

Enhance inter-sectoral coordination. A common objective of standard sanitation policy, coordination is particularly important for climate change because of the interconnected nature of damages and disaster response. Experts in emergency response, disaster risk reduction and other fields may need to be involved in sanitation working groups, and at the same time, sanitation stakeholders should be encouraged to participate in task forces on climate change, disaster risk reduction and water resource or flood management. Monitoring, warning systems and response to extreme events (see Section 7 below) to both inform the sanitation sector prior to hazards and alert other sectors to changes in sanitation system performance and their implications.

Promote adaptive management. A management strategy based on continual learning through experimentation and innovation prioritises learning, feedback and responsiveness to uncertain conditions. It can include (i) anticipatory or proactive adaptation before impacts (e.g., regular monitoring and maintenance of pump stations or trucks); (ii) responsive (or emergency) adaptation to changes in the system (e.g., worsening downstream water quality or disease outbreaks); and (iii) planned adaptation based on deliberate policy decisions to maintain or achieve a desired state (e.g., upgrading sewers or treatment to bigger capacity) (IWR, 2013). Adaptive management is typically win-win, and sanitation service models should include these principles in the set-up by establishing asset management systems, linking monitoring with response (e.g., customer complaints) and developing the financial arrangements to support this.

Consider decentralised or co-mangement models. Decentralised approaches to governance may create greater flexibility, knowledge sharing and improved response to hazards. Decentralising service provision could include diverse service providers for emptying or allowing community-based organisations to manage loan programmes for toilet construction. Co-management, whereby government and community groups agree on respective management responsibilities, is considered more sustainable for decentralised sanitation solutions (Mills, et al., 2017). Climate risks and adaptation strategies need to be communicated from national to local governments and service providers who are responsible for day-to-day operation and management.

Improve disaster response. Climate change requires stronger emergency and disaster response mechanisms. Effective, coordinated, gender-sensitive and socially aware processes for restoring sanitation services during and after disaster take on increased importance. This should include options for interim sanitation solutions when restoring systems is not immediate, such as emergency toilets or provisions for faecal sludge emptying. Disasters also offer opportunities for sanitation systems to be built back better. National sanitation sectors should consider how recovery efforts can rebuild sanitation systems that are more resilient and equitable.

Adopt policies that target inequality. Enhancing equity in access to sanitation is critical in emergencies, when competition for funds and services intensifies. A lead agency should be responsible for conducting a vulnerability assessment to understand how sanitation access, use and operation by potentially disadvantaged groups, including women, may be affected disproportionately by climate change. For example, safety and privacy may be compromised during emergencies. Assessments can include how power relations may influence access to services and make recommendations on how vulnerable groups can be supported (e.g., with knowledge or technical or financial support).

3 Sustainable and responsive financing

Plan for higher operation and maintenance costs. It is likely that operation and maintenance costs for sanitation services will increase with climate change, for two reasons: (i) increased need for repairs or replacement due to potential climate change-related damage; and (ii) additional monitoring and preventative management to improve adaptiveness. The full life-cycle costs — and responsibility for bearing them — should be identified in upfront options assessments, in particular for co-managed or decentralised systems. The additional operation and management expenses should not place a greater burden on vulnerable communities (as could be the case with mandated regular emptying).

Identify climate change funding. New sources of sanitation funding may include international climate finance for adaption and resilience (WaterAid, 2017). Coordination with other sectors or national climate strategies may help proposals for sanitation projects meet climate financing criteria. Agencies may need support to improve their financial management systems so that they can meet donors' readiness requirements (Oates, et al., 2014; WaterAid, 2017).

Recognise vulnerable communities. Some vulnerable communities face increased risk of exposure but less capacity to respond, and more resilient options may be beyond their ability to pay. In such cases, additional support, such as subsidies, will be needed. Additional funding for adaptive strategies should prioritise vulnerable groups (OHCHR, n.d.). It is often challenging to target adaptation efforts and produce results at local levels, where vulnerabilities to climate change play out. However, innovative solutions do exist. For example, in Kenya the Country Climate Change Funds devolve power to communities that identify and fund their own adaption plans (WaterAid, 2016). Greater incorporation of sanitation within these local climate adaptation plans may help vulnerable communities prepare and respond.

Regulate tariffs. Unregulated tariffs may make services unaffordable for vulnerable households as they often increase in periods of high demand, such as the increased demand for emptying during heavy rainfall or periods of raised groundwater levels. In Bangladesh users pay 15% more for emergency emptying, and the tariffs are often negotiated (SNV, 2017). At the same time, low-income settlements are often restricted to informal manual emptying services because trucks cannot enter populous areas with narrow passageways. Introducing citywide cross-subsidised tariffs and formalising manual emptying tariffs could make emptying services more equitable and affordable.

Provide rapid access to finance. Stakeholders (government, service providers, community, users) may need to undertake both preventative and responsive adaptions, and improved budgeting and planning mechanisms are needed to make funds available. This might include emergency loans for rebuilding household toilets or faecal sludge emptying. Community-scale or centralised sewerage systems may also need emergency finance, above usual planned maintenance, to repair damaged infrastructure. This may require new budget line items and fund allocations, as well as accountability measures to regulate how these funds can be used. Users, in particular vulnerable groups, will need information on how to apply for funds, and different methods to distribute the funds, such as local women's or community groups, or partnering with banks or other service providers, should be considered.

4 Infrastructure and service provision

Build operators' knowledge about existing systems. Adaptive management requires that operators and managers are well versed in the design of infrastructure and service models and receive comprehensible climate data to inform adaptations. An understanding of the current sanitation system — its capacity and performance and how it might react to different climate scenarios — is the first step. Operators or service providers (public, private and community) also need at-time information on climate hazards and the potential adaptive actions.

Develop no-regret adaptations that work in all scenarios. Some adaptations of existing infrastructure are considered no or low regret, in that they will be an improvement suitable to all future climate scenarios. Examples include options that use resources sustainably, such as low-energy treatment systems, low-flow toilets and greywater recycling. If existing infrastructure is in poor condition, simply fixing the system and optimising its capacity would be win-win. Nature-based solutions ('green infrastructure') have potential applications in urban sanitation. For example, natural filtration systems can treat wastewater or greywater while restoring natural waterways can help to mitigate flood hazards (WWAP and UN-Water, 2018). No-regret options should be examined critically to preclude maladaptation (adaptations that inadvertently cause negative effects), and opportunity costs should be considered prior to implementation (Preston, et al., 2015).

Weigh robust versus repairable infrastructure. To withstand the predicted shocks from climate hazards, sanitation technologies can be made 'climate-proof' — more robust to climate hazards. Examples include raising toilets above flood levels, increasing structural strength of treatment systems or sewers adjacent to waterways, and locating sanitation infrastructure to minimise potential damage. Another approach is to deploy low-cost sanitation technologies that can be quickly rebuilt, provided they do not create public health or environmental threats if they fail. For example, households could use temporary, alternative latrines whilst their primary latrines are being rebuilt after a shock. This presumes the availability of products, markets, finance and services for immediate rebuilding. There is tension between these two approaches — build robust to resist climate hazards versus build low-cost for frequent quick repair. The context will determine which approach is more appropriate.

Prioritise flexible technical and service solutions. Sanitation systems and service models need flexibility for two reasons: (i) to operate under a range of climate conditions; and (ii) to ensure that failures in one part of the system or model do not interrupt the service altogether. For example, water-based sanitation systems (sewers, wastewater treatment plants) may need to operate under both drought and flood conditions and should therefore be designed accordingly. Varied operational strategies (bypasses and cross connections) and decentralised systems will allow a failure to be isolated while the wider system continues to function.

Make operation and maintenance flexible. Although robust technologies are designed for specific climate shocks, managers must also consider the less extreme but more chronic disturbances and stressors, such as gradual changes in annual rainfall or more frequent floods. Adaptive operation and management should include monitoring the conditions (dry or wet) and developing ways to adjust operations accordingly so that they are sustainable under increasingly unpredictable conditions. Adaptive management not only reduces damage to the system from ongoing disturbances but also builds capacity to manage bigger shocks when they occur. Monitoring and reporting of both climate conditions and sanitation systems help operators and users prepare for hazards and take preventative measures. Such measures might include diverting treatment flows to avoid damage to pumps or biological processes, desludging containment before the rainy season and clearing solids from sewers and drains.

5 User engagement and awareness

Communicate climate change to sanitation users. Discourse on climate change is full of jargon and scientific terminology that can confuse and even alienate the public. Effective communication uses language that is understandable to the intended audience yet accurate and focussed. Strategies include using familiar terms as proxies for scientific language, discussing climate change projections in the context of current weather variability and extremes and focussing on essential messages, with no extraneous details. For example, one can convey the message that rainfall may become more intense in the rainy season without having to explain the concept of average annual rainfall (McNaught, et al., 2014).

Conotextualise climate change within lived experiences. Sanitation users may internalise the threat of climate change in ways that are counterproductive for sanitation management and adaptation. Sanitation problems due to poor management or poor services may be blamed on climate change. Or the threat of climate change may cause anxiety or feelings of hopelessness. Climate change should therefore be discussed in the context of sanitation users' lived experiences and challenges, with a focus on what they can do to help themselves and others in the near term (McNaught, et al., 2014). Solutions can be presented at the same time that the consequences of climate change are described, for example, ways that women can manage menstrual hygiene needs during a disaster can be shared as part of awareness-raising efforts.

Provide information to help users respond. Sanitation users require timely information about potential hazards, likely impacts and options for advance preparation and post-event response. Information systems that reduce public uncertainty can minimise disruptions and hasten recovery. An example is warning systems to alert the community to a coming storm, water contamination or disease outbreak. Communicating such information to the most vulnerable groups may require concentrated effort or alternative approaches. Building on traditional knowledge or practices can increase the likelihood of adaptation practices (OHCHR, n.d.).

Include the community in decision making. In developing countries households play an important role in the management of sanitation. Participatory decision making — an increasingly common approach in urban sanitation planning — is particularly important in considering climate change, for both increasing community capacity and addressing gender equality and equity. Involving potentially disadvantaged groups, including women, in decision making can build their capacity to take independent action and ensure that different needs are voiced and met. In climate change adaptation planning, participatory processes should represent different interests in framing the problem, support learning opportunities for all and generate new ideas for adaptation pathways (Ensor, et al., 2015).

Consider special needs of vulnerable communities. Specific efforts should be made to engage, include and support vulnerable communities — groups that commonly live in areas more susceptible to climate change hazards, such as along waterways. Different methods may be required to engage with these communities and respond to their challenges.

Increase users' willingness-to-pay. As described under Section 3 (Sustainable and responsive financing), the costs of a more climate-resilient sanitation system may be high. Some of these costs may be underwritten by governments, but it is likely that users will also need to pay more. User funding for even standard sanitation services is a challenge. Nevertheless, enhancing public understanding of the full cost of providing adaptable, climate-resilient sanitation services will be important for increasing willingness-to-pay amongst users.

6 Water cycle, environment, and public health

Coordinate water and land resource management strategies. As the environment changes and resource management strategies are revised, the sanitation sector needs to be involved in decisions and plans for the urban water cycle and urban planning more broadly. Of particular importance is understanding changes to upstream water resource and flood management and their effects on cities' assets, services and operations. Integrated water resource management (IWRM) strategies, such as monitoring water availability and allocating water resources for domestic purposes, can help ensure that water-based sanitation services remain functional (Hadwen, et al., 2015). Sea-level rise may flood or erode sanitation infrastructure, so strategies may be needed to incrementally move infrastructure away from exposed areas. Changes in population density or land use due to climate change may also affect the planning and locations of sanitation infrastructure and services.

Consider downstream effects of poor sanitation. Climate change can exacerbate the environmental impacts of sanitation. Both wet conditions that cause more frequent overflows and dry conditions that reduce capacity for dilution in receiving waterways may increase water pollution. Flows in receiving waterways and pollution levels in downstream waterbodies should be monitored and inform action — whether changes in treatment operation or warnings to downstream users. Besides the standard sanitation improvements to manage faecal waste, options to reduce the quantity of wastewater entering the environment include green infrastructure (e.g., wetlands, swales), water demand reduction and on-site reuse.

Address potential public health risks. Failures in sanitation service delivery in low-income countries release pathogens across the urban environment, and future climate hazards are likely to exacerbate people's exposure. Flooding or heavy rainfall can spread pathogens from drains and uncontained toilets or tanks, and faecal matter can also enter the environment through open defecation or dumped sludge. Prolonged inundation heightens the risk of waterborne disease outbreaks and the speed of spreading. Rising water tables, caused by sea level rise or prolonged rainfall, may increase the contamination of groundwater by unsealed pit latrines or leaking sewers. In droughts, the concentration of pathogens in waterways will increase while in parallel, a likely increased demand for water reuse can lead to greater risks for agricultural workers and the contamination of produce. Understanding the interconnected nature of the urban water cycle and developing methods to reduce exposure and risk will be even more important with climate change, including identifying who is most at risk, paying particular attention to vulnerable populations. The WHO sanitation safety planning approach (WHO, 2015) explains the risk of pathogen exposure across a city; it also suggests methods to reduce exposure.

Meet multiple objectives. Integrating urban sanitation systems with wider water, food and energy systems can deliver win-wins as the climate changes. Wastewater reuse can alleviate water scarcity. Nutrient recovery from sludge and wastewater reuse can address fertiliser scarcity. Sludge reuse can replenish the soil and enhance its water-holding capacity, thereby providing a buffer against drought. Generating and capturing biogas from human waste can reduce reliance on fossil fuels in sanitation treatment. Biogas can also be used in decentralised systems for lighting or cooking. Prioritising such multiple objectives depends on a city's needs. For example, where food security is a major problem, sanitation investment could focus on reducing contamination in the food chain.

Reduce the contribution of urban sanitation to climate change. There is opportunity to lower the energy intensity of urban sanitation systems by using green infrastructure or decentralised systems to reduce pumping requirements. There is also opportunity to consider wastewater treatment options with lower greenhouse gas emissions. Carbon dioxide, methane and nitrous oxide emissions, for example, can be reduced by changing operational conditions, or through additional processes to remove organic matter and pollutants. For example, greenhouse gas emissions can be reduced if micro-algae or nitritation-Annamox processes are used rather than conventional nitrification-denitrification (Campos, et al., 2016).

7 Monitoring, evaluation, and learning

Establish warning systems. Early warning alerting stakeholders to impending flooding, drought or other severe weather allows preparation measures to be taken (e.g., turning on-off valves to divert flows and minimise system damage, ensuring back-up pumps and storage are online, protecting piles of sludge from heavy rain). Warning systems need to be preceded by awareness raising on how to minimise risks during and after climate events, such as avoiding exposure to flooded areas, treating drinking water (especially groundwater) or how to access support services. Warnings should also be issued for known discharges of untreated wastewater to the environment, with signs posted at sewer overflow locations and public announcements about not swimming in waterways.

Set up rapid review-and-response strategies. Reviews are essential for adaptive management. System performance should be monitored regularly, not just during specific climate events. The emphasis should be on generating data when needed and building capacity to respond.

Review and re-set objectives. Reflecting on the success or limitations of plans and approaches enables evolution of response strategies. Longer-term reviews are also important to consider new knowledge, such as updated information about climate trends and the different risks and hazards for different groups of people.

Monitor effects and needs across groups. Both rapid and long-term monitoring systems must consider the different needs and challenges across locations and social situations, with a particular focus on disadvantaged groups that are at higher levels of exposure and have less resilience to climate-related events.

Coordinate with other sectors. Inter-sectoral coordination is important for monitoring and warning systems. For example, data on tides, floods and water shortages help the sanitation sector modify its service operations, and changes to transport networks may affect emptying services. Similarly, water supply, agriculture, public health and recreation authorities should be alerted to problems in sanitation systems that could harm the quality of local waterways.

Summary: doing urban sanitation differently because of climate change

The policy and programme actions that would increase the consideration of climate change in urban sanitation are summarised in Table 1. Although the proposed actions are ambitious, not all need be adopted immediately or concurrently. Rather, this summary serves as a reference for steps towards greater consideration of risk-hazard, vulnerability and resilience for urban sanitation. Because numerous activities compete for prioritisation in urban sanitation, at a minimum, governments and development partners may wish to consider how their plans could be modified to incorporate concerns about climate change.

Table 1 Policy and programme actions for greater consideration of climate change in urban sanitation

• Pillars	Urban sanitation policy and programme actions
Planning and decision making	• Raise awareness and build understanding of local climate change hazards and social distribution of effects (e.g., by sharing climate data and assessments). • Plan for varied climate scenarios (e.g., by considering potential for both wetter and drier conditions). • Make climate resilience an objective of urban sanitation decisions (e.g., by including flexibility or adaptiveness in multi-criteria assessments, and planning to meet needs of vulnerable groups). • Consider how sanitation fits with planning of broader urban systems to maximise overall system resilience (e.g., consider flood management, disaster risk reduction, water security). • Prioritise infrastructure options that meet immediate needs and achieve long-term sustainability goals (e.g., by focussing on basic access to toilets that are also water efficient or resilient to flooding).
Institutional arrangements	• Include climate-relevant stakeholders in sanitation working groups and encourage sanitation actors to engage with cross-cutting sectors (e.g., emergency response, water resources, flood management). Inter-sectoral coordination is important for monitoring, warning and response systems. • Institutionalise adaptive management practices as part of sanitation management to facilitate anticipatory, responsive and planned adaptation (e.g., by implementing systems and funding staff for monitoring and learning). • Consider flexible management options such as decentralised or co-management arrangements to share knowledge and improve response to hazards (e.g., co-management of communal systems or multiple emptying providers). • Improve disaster response and recovery. Include gender-sensitive and socially sensitive processes for restoring sanitation during and after a disaster (e.g., by providing emergency toilets for short-term use) and rebuild systems that are more resilient and equitable. • Target inequalities by assessing the vulnerabilities of different social groups (e.g., through national policies that assign local responsibility, with accountability and compliance mechanisms).

Sustainable and responsive financing	• Plan for increased operation and maintenance costs associated with climate change and adaptive management (e.g., by including full life-cycle costs in options assessment). Consider who bears these costs and their ability to pay. • Identify climate change funding sources for sanitation adaption and resilience projects and support authorities meet application requirements (e.g., by building financial management systems that cover climate fund readiness criteria, with separate line items and reporting for climate change activities). • Recognise additional financial needs of vulnerable communities and target adaptive strategies to support their needs (e.g., by prioritising funding for adaptive strategies that will help vulnerable groups). • Regulate tariffs to ensure equity in periods of high demand or increased competition for services (e.g., by formalising tariffs for desludging, possibly cross-subsidising fees for disadvantaged or vulnerable groups). • Set up responsive financing mechanisms to allow all actors to access funds for both pre-emptive adaption and rapid response to disasters (e.g., by establishing budget items for non-specified repairs and accessible revolving funds for low-income households to rebuild toilets or empty tanks pre- or post-hazard).
Infrastructure and service provision	• Build operators' knowledge about existing sanitation system and climate change risks to enable adaptive management (e.g., by involving operators in design and decision making, by providing timely information on climate hazards and options to respond). • Prioritise no-regrets adaptation that anticipates all climate conditions (e.g., by optimising operation of existing system, prioritising resource efficient infrastructure). • Consider whether 'robust' sanitation (i.e., higher-cost climate-proof systems) or 'repairable' options (i.e., lower-cost infrastructure that can be quickly rebuilt) make more sense in given context and climate risks. • Prioritise flexible technical and service solutions (e.g., by using decentralised systems, sewer diversion options, multiple emptying providers). • Establish operations and maintenance systems that enable adaptive management (e.g., by creating asset management system that links monitoring with response).
User engagement and awareness	• Communicate with sanitation users about climate change hazards (e.g., by holding meetings to explain potential climate hazards using familiar and simple language). • Contextualise climate change within lived experience of users and focus messages on how they can respond in near term (e.g., by comparing climate change risks with recent disasters and the associated sanitation problems). • Provide timely information to enable user preparedness and responsiveness with conscious effort to reach vulnerable groups (e.g., by setting up information and warning systems before, during and after events, by providing support for response). • Include community and users in decision making to build knowledge, agency to take action and skills to adapt and manage systems (e.g., by involving community and explaining decisions about sanitation system options, design and operation). • Consider special needs of vulnerable communities and prioritise support for these groups (e.g., by tailoring outreach and response efforts). • Increase willingness-to-pay amongst users to defray increased costs of climate-resilient sanitation services.
Water cycle, environment and public health	• Work with other sectors on water and land management strategies to understand and reduce disruption to urban sanitation systems (e.g., by considering water resources and land-use plans when designing and siting sanitation infrastructure). • Mitigate downstream effects of climate change impacts on sanitation (e.g., monitor downstream water quality to inform action, reduce wastewater discharge through low-flow sanitation or on-site reuse). • Address potential for pathogen exposure in urban environments and consider how climate change may shift exposure and risks for different populations (e.g., by identifying risks through sanitation safety planning). • Consider opportunities to meet multiple objectives with sanitation improvements and look for win-wins (e.g., by using human waste as fertiliser and soil conditioner, by generating biogas for energy). • Reduce contribution of urban sanitation to climate change with options that have low energy intensity or low greenhouse gas emissions (e.g., reduced pumping requirements by choosing decentralised system or modifying treatment processes to reduce emissions).

Monitoring, evaluation and learning	• Establish warning systems and promote awareness of how to minimise risk (e.g. by issuing early flood warnings that allow time for opening/closing valves, by educating users about avoiding drains and treating water following an event). • Develop rapid review and response strategies to enable adaptive management (e.g., by collecting data to track system performance during both normal operation and extreme events). • Review and re-set long-term objectives and develop response strategies (e.g., by incorporating new information about climate trends and risks for different groups). • Monitor effects of climate related events on safe sanitation for different social groups (e.g., by establishing disaggregated data protocols). • Coordinate monitoring efforts with water supply, public health, transportation and other sectors whose operations affect or are affected by sanitation (e.g., by setting up systems to share timely information).

Conclusions

Applying vulnerability and resilience perspectives to urban sanitation services, we see it is not just sanitation infrastructure that must be resilient to changes, but also the interconnected social, institutional and physical systems. Whereas the literature on climate and urban sanitation has generally focussed on the risk-hazard perspective, this paper has identified new impacts, particularly for users and service providers, whose capacities must be developed to better respond to climate change and its uncertainties. We have also identified the potential burdens on vulnerable groups — burdens that risk exacerbating inequities in access to sanitation services.

Our systems mapping demonstrates the complexity of synthesising and predicting climate change effects on urban sanitation performance, given the many interconnected pathways and consequences. To guide a more systematic approach to analysis, this paper proposes six principles drawn from theories and concepts explored in climate change literature: (i) optimised and robust hardware to sustain shocks; (ii) flexible options and diversified risk; (iii) adaptive management to withstand disturbances; (iv) raised awareness and knowledge to minimise damage; (v) consideration of complex system dynamics; and (vi) attention to the distributional effects on equity.

Those principles can guide new thinking about how the urban sanitation sector responds to climate change. Recognising the multiple actors and the need to consider the interwoven social and bio-physical systems relevant to urban sanitation services, we identify seven pillars as the basis for a systematic approach to identify and prioritise climate change action in planning and policy: (i) planning and decision making; (ii) institutional arrangements; (iii) sustainable and responsive financing; (iv) infrastructure and service provision; (v) user engagement and awareness; (vi) water cycle, environment and public health; and (vii) monitoring, evaluation and learning. For each pillar we have presented ideas and examples for addressing climate change effects on urban sanitation systems and services.

Competing priorities and uncertainties can lead to inaction. In many cities in developing countries, planning for climate change hazards is currently perceived as a secondary concern given the major efforts needed simply to establish functioning urban sanitation systems. However, as global warming pushes climate variability to new extremes, the hazards will increasingly demand attention. Uncertainty should not be a reason for inaction, particularly since strategies that are designed for uncertainty (such as adaptive management) are often also win-win.

Some may argue that all sanitation improvements reduce risks due to climate change, or that considering climate change could distract from progress in urban sanitation but ignoring the issue will likely cause unintended negative effects to some populations be missed. Viewing urban sanitation through risk-hazard, resilience and vulnerability lenses reveals a range of social and physical consequences and suggests new and different priorities for building the enabling environment. The major differences from usual practice include the following dimensions:

- Addressing uncertainty brings a particular focus to improving the operation and management of services and ensuring flexibility, adaptability to changing conditions and diversification of risk.

- Increasing focus on monitoring and response facilitates adaptation to disturbances and builds capacity to respond to shocks.

- Diversification of risk should consider decentralised systems (not relying on one system or one provider) and management (shared responsibilities and capacity). Reducing risk is common in technology design but less so in other sanitation decisions — for example, for management and service responsibility.

- Decision making must consider flexibility and adaptability to uncertain conditions, equity (particularly for vulnerable populations), increased operational costs and trade-offs (such as between easily rebuilt and robust systems).

- Adaptation is dynamic and learning and reflection are critical. Deficiencies here are a particular weakness of today's urban sanitation systems, and the sector as a whole is chronically under-managed.

Many cities struggle to deliver basic, equitable sanitation services with limited technical, financial and institutional capacities, let alone meet the ambitious aspirations of the Sustainable Development Goal for safe sanitation. Efforts to address climate change in the sanitation sector need to be sensitive to the limitations and help build these capacities and do so in alignment with existing programmes and approaches. This paper has provided an overview of actions and considerations that could guide sanitation practitioners, donors and policy makers in ensuring that progress in this sector also addresses the risks posed by climate change. Delivering sanitation in an era of climate change requires that services be sustainable under evolving, uncertain conditions and that climate change adaptation be mainstreamed in urban sanitation policy and planning.

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USHHD LEARNING PAPERS

The USHHD (Urban Sanitation and Hygiene for Health and Development) learning paper series is an occasional SNV publication that presents the latest thinking and research on human waste management, across all types of premises. Each USHHD learning paper reflects on one or several components of SNV's USHHD interlinked components. These are: behaviour change communication and awareness; safe and affordable consumer services; WASH governance, regulations and enforcement; smart finance and investment; improved treatment, disposal and re-use; and knowledge management and learning. The series is part of SNV's mission to contribute to systems change. It facilitates the cross-fertilisation of knowledge, and imparts evidence-based and proven lessons, tools, and ideas that strengthen government, private sector and civil society capacity to launch and sustain city-wide and inclusive sanitation services.