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TRANSITIONING URBAN WATER AND SANITATION SYSTEMS: KEY ELEMENTS FOR SUSTAINABLE CHANGE

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Abstract

Significant gaps and inequities in urban water and sanitation services persist, with a growing risk of exacerbation due to changes in the climate, global water cycle, and patterns of urbanisation. Urban water and sanitation systems need to transition to accelerate access to safe, equitable, and sustainable water and sanitation services, while enhancing resilience to respond to increasing risks. This paper reviews the persistent challenges in water and sanitation services, emerging risks from climate change, and imbalances in the global water cycle that threaten to impact urban water cycles, and potentially disrupt existing urban Water, Sanitation and Hygiene (WASH) systems. It identifies critical concerns in three areas: institutional arrangements (including informal service provisioning), technology and infrastructure, and financing (including operations and maintenance). The paper concludes by identifying critical elements required in these areas for successful transition of water and sanitation services and systems.

1. Introduction

Safe drinking water and sanitation is fundamental to human health and well-being. Although the global burden of disease due to enteric infections, often caused by contaminated food and water, reduced by 66 per cent between 1990 and 2021 (IHME, Global Burden of Disease 2024), unsafe water and sanitation continue to cause an estimated 1.4 million deaths annually (WHO, 2022a). Diarrheal diseases, including cholera, account for most of this burden and are spreading alarmingly due to climate change and conflict.

As urban areas expand, now encompassing 57 per cent of the global population (World Bank, 2018), 0.6 billion urban residents lack access to safe water, and 1.7 billion lack access to safe sanitation (UNICEF & WHO, 2023). Severe gaps persist in securing the full cycle of urban water and sanitation[1]. Although no region is on track to meet Sustainable Development Goal (SDG) 6 for universal access to drinking water and sanitation services, some areas, such as Latin America and the Caribbean, have regressed in terms of drinking water coverage (UNICEF & WHO, 2023).

WASH systems are “all the social, technical, institutional, environmental and financial factors, actors, motivations and interactions that influence WASH service delivery in a given context” (Huston & Moriarty, 2018). The economic implications of this are significant, with inadequate WASH systems leading to economic losses of approximately USD 260 billion annually in 136 low- and middle- income countries (UN-Water, 2021).

While cities continue to struggle with the classical challenges of inadequate access, unsafe, and unreliable services, their WASH systems must also adapt to the challenges posed by climate change, such as water scarcity (too little), floods (too much), disruptions due to extreme events and significant water quality risks (too dirty) risks, where blue water is contaminated by black and grey water (Grafton et al., 2023). Although water for domestic use (urban and rural) accounts for only a small percentage of total water use (approximately 10 per cent), securing this water in the context of changing climate is critical for human health.

Water and sanitation systems need to transition to address these emerging challenges while simultaneously expanding to meet the needs of those without access. In addition, urban WASH systems have the potential to reduce environmental impact by incorporating water-use efficiency, energy efficiency, and minimising environmental contamination (water, soil, and air) at each stage of the full cycle of water and sanitation.

The paper outlines the gaps in global progress towards SDG 6, highlighting key regional differences and data gaps in considering each component of the full cycle of urban water and sanitation. It synthesises the latest evidence from research and practice on the challenges underlying these persistent gaps in urban WASH and frames the analysis of these challenges by focusing on four key areas — institutions, technology and infrastructure, costs and funding, and behaviour change. The paper also explicates critical elements around each of these areas to offer key recommendations to achieve desired water and sanitation outcomes.

The paper is structured as follows: the interaction between the Global Water Cycle, the Urban Water Cycles and the Urban WASH systems (section 2), review of the current status of water and sanitation systems (section 3), impact of urban growth on urban WASH systems (section 4), analysis of the status and challenges in water and sanitation services (section 5), followed by a concluding section with recommendations to accelerate urban water and sanitation transition (section 6) .

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[1] The full cycle of urban water and sanitation includes extraction, storage, and treatment of water, which is then supplied to various users. After consumption, the resulting wastewater is collected, conveyed, treated and either disposed of or reused.

2. Interaction between the Global Water Cycle, Urban Water Cycles and Urban WASH Systems

The Global Water Cycle (GWC) is an intricate system encompassing oceans, atmospheric water, soil, and terrestrial water bodies. This cycle is sustained by the continuous exchange of water between these reservoirs through processes like evapotranspiration, precipitation, and runoff, collectively referred to as components of the water cycle. These fluxes are significant and play a crucial role in supporting life and human activities (Oki et al., 2004).

However, the GWC is being rapidly altered by the growing global population, increasing demand driven by economic prosperity and urbanisation, and mounting ecological stress exacerbated by climate change (Ligtvoet et al., 2018). Human-induced changes have altered the GWC across local to global scales, including 'changing the source of all freshwater, precipitation, and triggering extreme water events' (Douville et al., 2021; McGrane, 2016; Grafton et al., 2023). These changes have led to a global water crisis, often manifested as water scarcity (too little), floods (too much), and water pollution (too dirty), impacting millions of people and posing significant challenges to sustainable development from local to global scales (Güneralp et al., 2015; He et al., 2021; Pörtner et al., 2022; Grafton et al., 2023).

The GWC and climate change are intricately interlinked. IPCC assessments show that human-caused climate change has altered the global water cycle since the mid-20th century and will continue to reshape it on both global and regional scales (Pörtner et al., 2022). The impact of climate change on the water cycle is being observed through rising sea levels, precipitation variability, evapotranspiration, very dry and wet events including occurrences of floods, droughts, and extreme events (Pörtner et al., 2022). These climate-induced impacts will worsen with increase in global temperatures. Changes to the GWC, such as shift in precipitation patterns or changes in runoff, can directly affect the availability of water resources. This might lead to periods of water scarcity or abundance, influencing water management strategies and infrastructure planning.

In urban settings, though the principal structure of the water cycle remains the same, it becomes more complex due to the impacts of urbanisation on the environment, and the necessity of providing essential WASH services such as water supply, drainage, and wastewater management for urban residents, especially in dense settlements. This modified water cycle with added components such as WASH services is referred to as Urban Water Cycle (UWC) (Marsalek, 2006). One of the key features of the UWC is import of water from outside urban boundaries or catchments. UWC is part of the GWC and is impacted if there are changes in GWC. For example, changes in GWC will change the availability of water within the urban boundaries which leads to increased reliance on water import.

The UWC while inherently linked to the broader GWC, becomes increasingly vulnerable as climate-induced changes to the GWC intensify. As urban areas rely on external water sources and experience growing pressures from urbanisation, disruptions to the GWC, such as extreme weather events and shifting oceanic patterns, exacerbate water scarcity and infrastructure challenges. Consequently, urban WASH systems face heightened risks from extreme events such as floods and droughts. Increased frequency and intensity of rainfall, storm surges, can cause urban inundations, pose risks to human life and well-being, damage infrastructure, contaminate water sources, and disrupt essential services. However, due to the interplay between thermodynamic processes and atmospheric dynamics, predicting whether such events will increase in a specific location remains uncertain. Additionally, non-greenhouse gas factors—such as aerosols—may also play a significant role in affecting rainfall patterns, potentially masking or intensifying the impact of greenhouse gas emissions (Philip et al., 2019). Further, droughts can reduce water availability and place additional strain on aging infrastructure (Wang et al., 2022), droughts and depleted groundwater levels can increase water stress, impact food security, and cause natural contamination, including higher levels of fluoride, arsenic, solids, iron, nitrate in groundwater (Famiglietti, 2014; Gorelick & Zheng, 2015).

Sudden shifts in ocean circulation patterns, rapid glacial collapse in polar regions leading to rising sea levels, and the accelerated melting of snow and ice significantly impact the GCW. These disruptions can result in reduced snowmelt runoff and trigger rain-on-snow events, which further exacerbate flooding and water availability issues (Seibert et al., 2021; Lagerloef et al., 2010). As urban infrastructure is not always built to withstand extreme weather events, retrofitting and upgrading become essential to enhance resilience. This includes reinforcing drainage systems to cope with storm surges and adapting water storage infrastructure to maintain supply during droughts (Wang et al., 2022).

It is estimated that by 2050, environmentally critical streamflow will be affected in 42–79 per cent of the world's watersheds (Lee et al., 2021), resulting in decreased flows to urban reservoirs and threatening the sustenance of urban water services. In regions like South and Southeast Asia, nearly three-quarters of the urban land is at risk of high-frequency floods (Güneralp et al., 2015). Additionally, South Asia, South America, and mid-latitudinal Africa are projected have the largest urban areas exposed to floods and droughts (Güneralp et al., 2015), which disrupt water and power supplies and cause damage to WASH infrastructure.

In addition to GWC impacts, urban WASH systems are increasingly affected by other changes in the ecosystem. WASH is closely connected to five of the nine planetary boundaries (Rockström & Noone, 2009; Steffen et al., 2015), including the three that have already been transgressed: climate change, rate of biodiversity loss, and changes to the global nitrogen cycle (Carrard & Willetts, 2017).

Conversely, the UWC has a limited impact on GWC. Although urban WASH water demand has increased substantially in recent years, water for WASH accounts for only around 10 per cent of global water demand (Grafton et al., 2023), indicating that agricultural and industrial water use have a greater influence on the GWC. However, due to a lack of clarity on the exact end use of water, especially in industrial and urban areas, consumption by other sectors is often incorrectly attributed to the agricultural sector.

There are other ways in which UWC is impacting GWC. Globally, WASH water use intensity was around 400-450 km^3/ year in 2010 and is projected to reach 700-1,500 km^3/year by 2050 (Lee et al., 2021; McDonald et al., 2014; Wada & Bierkens, 2014). This suggests growing water stress, especially in urban areas, necessitating increased reliance from distant sources, major infrastructure investments and more efficient water management due to rising costs and energy consumption.

WASH water demand is met by extracting water from a mix of surface and groundwater systems. In addition to water scarcity, poor water quality drives extraction from distant sources. With 42 per cent of total global domestic wastewater being discharged into the environment untreated (UN-Water, 2023), the quality of blue water[2] is reduced (by converting blue to black and grey), thereby diminishing its availability for key end uses. Large cities (population >750,000, representing 33 per cent of global urban population) obtain 78 ± 3 per cent of their water from surface sources, some of which are located far away (McDonald et al., 2014). These cities transport 184 km^3 of water annually over a distance of 27,000 ± 3,800 km (McDonald et al., 2014) resulting in approximately 29.4 million tonnes of CO_2 emissions each year[3].

The scale of this extraction can increase surface evaporation due to the greater amount of water in direct contact with the atmosphere, affecting the GWC (Douville et al., 2021).

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[2] The water in the lakes, rivers and aquifers are referred to as blue water. Blue water occurs in two different forms: surface runoff in surface waterbodies and renewable groundwater runoff in the aquifers.

[3] Energy consumption for delivery of imported water is 4.7 kWh/ m^3 over 575 km and CO_2 emission 3.4 kg/m^3 (Yaron, 2022)

The implications of the interaction between GWC, UWC and WASH systems are:

1. Challenges such as water scarcity, flooding, and emerging contaminants are impacting the safety, sustainability, and resilience of urban WASH systems.
2. Urban WASH equipment, which typically have a life span of 15 to 20 years (Laakso et al., 2019) (with Sewage Treatment Plants lasting more than 50 years (NetSolWater, n.d.), is designed based on historical water availability and demand patterns. Since these are influenced by the GWC, the infrastructure may need to be retrofitted or expanded in response to changing conditions, requiring a reassessment of planning and design assumptions. This includes reservoir management, distribution systems, stormwater management, and wastewater treatment facilities.
3. There is a need to diversify water sources beyond traditional ones like rivers and groundwater. Such diversification needs different types of distribution and treatment systems, such as combination of decentral and central, or transitioning from one type of system to the other. To manage these transitions, institutions and governance structures have to evolve alongside other enablers such as technology.
4. Urban areas are where the challenges of changes in the GWC are complex and acutely felt, and the solutions developed in these settings have significant potential to be scaled up and applied in other contexts, across the urban-rural continuum including different settlement types and sizes, such as metropolitan cities to small and medium towns.

3. Current Status across Water and Sanitation Systems

The full cycle of urban water and sanitation includes the extraction, storage, and treatment of water, which is then supplied to various users; after consumption, the resulting wastewater is collected, conveyed, treated, and either disposed of or reused. Various components of this full cycle are tracked and monitored as part of SDG 6. However, there are gaps, with components such as water storage and wastewater reuse not being covered by the indicators.

Table 1: Stages of full cycle of water and sanitation and SDG 6 indicators

Stages of the full cycle of water and sanitation	SDG indicators
Water extraction	6.4.1 Change in water-use efficiency over time 6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
Water storage	None
Water treatment	6.3.2 Proportion of bodies of water with good ambient water quality
Water distribution / access	6.1.1 Proportion of population using safely managed drinking water services
Wastewater containment	6.2.1 Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water
Wastewater collection and conveyance	6.3.1 Proportion of wastewater safely treated
Wastewater treatment	6.3.1 Proportion of wastewater safely treated
Wastewater disposal / reuse	None

Source: (UN-Water, 2017a)

Tracking SDG 6.1 and 6.2 Progress

As we move closer to 2030, glaring gaps in universal and equitable access to safe drinking water (SDG 6.1) and sanitation (SDG 6.2) persist. In 2022, 73 per cent of the global population and 81 per cent of urban population had access to safely managed drinking water services, yet 2.2 billion people remain underserved. On the sanitation front, 57 per cent of the global population and 65 per cent of urban population had access to safely managed services in 2022, leaving 3.5 billion people without safe services. Additionally, 75 per cent of the global population had access to basic handwashing facilities, but nearly 2 billion people still lacked this essential service for preventing disease transmission (UN-Water, 2023).

While significant progress has been made, there is a considerable variation in progress, and deep inequalities persist across regions, within regions, and within countries. For instance, in Sub-Saharan Africa (SSA) urban drinking water services coverage in 2022 ranged from 11 per cent in Central Africa Republic to 80 per cent in South Africa. In Eastern and South-Eastern Asia, the coverage in urban areas ranged from 27 per cent in Lao PDR to 100 per cent in China and Singapore (UNICEF & WHO, 2023). In Northern Africa and Western Asia, access to safely managed drinking water services also varies widely. Gulf countries such as Kuwait (100 per cent), Qatar (97 per cent), Bahrain (99 per cent), Israel (99 per cent), Tunisia (76 per cent) have high access rates due to substantial investments in desalination and water infrastructure. In contrast, countries like Iraq (60 per cent), Georgia (69 per cent) and Lebanon (48 per cent) have lower access rates. Yemen, facing conflict and water scarcity issues, has no data on safely managed services, and even basic services are only at 62 per cent (UNICEF & WHO, 2023).

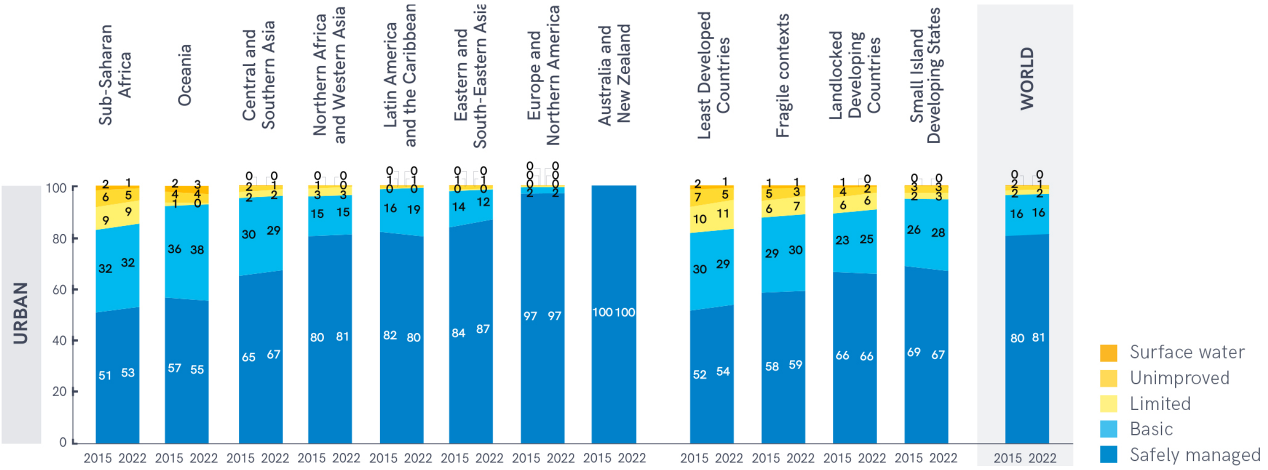
As with drinking water, intra-regional disparities in sanitation are stark across all regions. For instance, urban sanitation services coverage in Eastern and South-Eastern Asia ranges from 30 per cent in Thailand to 85 per cent in China and 100 per cent in Singapore in 2022. In Europe and North America, eastern European countries such as Serbia, urban coverage was only at 22 per cent in contrast to 100 per cent coverage in Switzerland, Austria, Andorra and Monaco (UNICEF & WHO, 2023).

Countries in Europe and Northern America generally have high levels of access to safely managed drinking water and sanitation services, given well-established infrastructure and regulatory frameworks. However, disparities still exist at more localised levels, affecting marginalised communities and areas with aging infrastructure. For example, while the Joint Monitoring Program (JMP) reported only a 0.01 per cent gap in 2019, Capone et al., (2020) identified that nearly 0.37 per cent of the urban population in the United States — about one million people — still lacked access to basic sanitation services based on regional survey data.

From 2015 to 2022, global access to safely managed drinking water services grew by four per cent (urban by one percent), while access to safely managed sanitation and hygiene grew by seven per cent (urban by five percent) (UNICEF & WHO, 2023).

Progress in urban coverage of safely managed drinking water services varied across the regions. While it marginally increased in Eastern and South-Eastern Asia, Central and Southern Asia and SSA, there was a slight decline in Oceania and Latin American and the Caribbean (UNICEF & WHO, 2023).

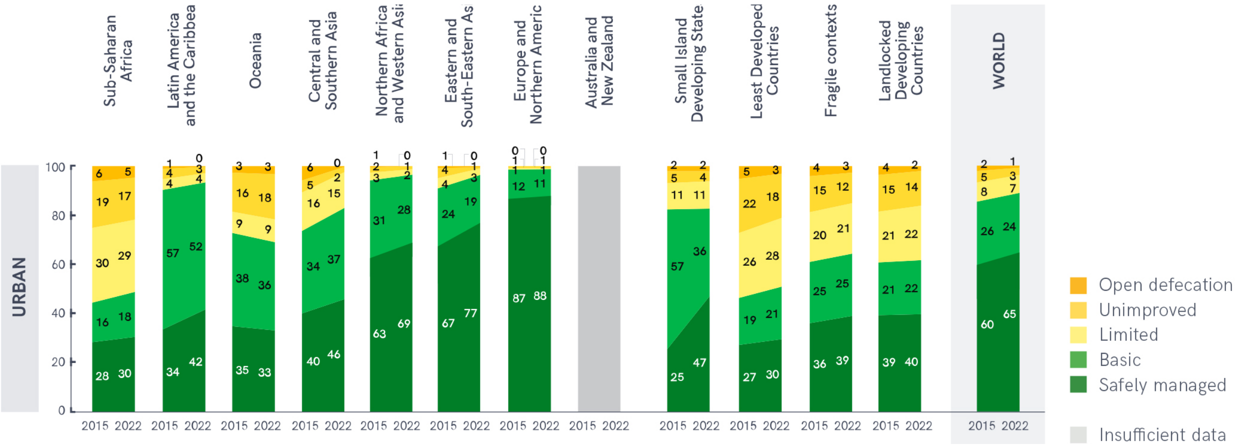
Figure 1: Urban Drinking Water Coverage, by service level and SDG region, in 2015 and 2022 (%)



Source: (UNICEF & WHO, 2023)

In terms of safely managed sanitation services, most regions saw an increase except for Oceania. The Eastern and South-Eastern Asia experienced the highest urban coverage increase from 67 to 77 per cent followed by Latin America and the Caribbean, where urban coverage grew from 34 to 42 per cent (UNICEF & WHO, 2023).

Figure 2: Urban Sanitation Coverage, by service level and SDG region, in 2015 and 2022 (%)



Source: (UNICEF & WHO, 2023)

Beyond these regional statistics, significant disparities in WASH access exist between urban and rural populations. In 2022, urban coverage of safely managed drinking water services was at 81 per cent compared to 63 per cent in rural areas. For safely managed sanitation services, urban coverage was at 65 per cent, while rural areas were at 46 per cent.

However, between 2015 and 2022, rural areas saw substantial improvements, largely attributable to their initial low coverage levels. Access to safely managed drinking water increased from 56 to 63 per cent compared to the 80 to 81 per cent in urban areas. Rural coverage for safely managed sanitation also grew from 36 to 46 per cent, with urban coverage increasing from 60 to 65 per cent (UNICEF & WHO, 2023).

Table 2: Population provided with safely managed drinking water and sanitation services in 2022

Country groups	No. of countries (As per WHO classification)	Safely managed drinking water services		Safely managed sanitation services	
		2015 (%)	2022 (%)	2015 (%)	2022 (%)
Low-income countries	26	24	29	28	35
Lower-middle income countries	51	56	62	61	74
Upper-middle income	54	83	86	86	94
High-income countries	86	95	94	99	>99

Source: UNICEF & WHO, 2023

There are notable differences between the rich and poor within countries as well (see Table 2). Existing data likely conceals larger and more significant inequalities with countries, especially when disaggregated by household income and gender (UNICEF & WHO, 2023). There is also limited focus on equity and inclusion, particularly concerning disparities within communities, marginalised groups, and on climate change and disaster risk resilience.

In five countries—Congo, Fiji, Georgia, Honduras, and Togo—the disparity between the richest and poorest quintiles exceeded 50 percentage points (UNICEF & WHO, 2023). Data also highlight that women and girls bear the primary responsibility for water collection in 80 per cent of households without access to water on premises (UNICEF & WHO, 2023; WHO, 2022b). The growing income gap and the uneven impact of environmental changes on regions and countries will likely perpetuate severe inequalities in access to water and sanitation (Sachs et al., 2023).

At the current pace of progress, achieving the 100 per cent target by 2030 seems unlikely. Projections indicate that billions will remain without access to these essential services by the end of the decade.

Table 3: Existing gap and required progress by SDG target

SDG 6	Coverage by 2030 (per cent)	People without services by 2030	Required increase in progress	Rate increase in LDCs and fragile contexts*
Safely managed drinking water	77	2 billion	Sixfold	14x and 19x
Safely managed sanitation	65	3 billion	Fivefold	16x and 15x
Basic hygiene services	84	1.4 billion	Tripling	27x and 18x

*LDC - Least developed Countries (UN classification)
Fragile context - Countries with high levels of institutional and social fragility, violent conflict (World Bank Classification)

Source: (UN-Water, 2023)

The estimated gap (see Table 3) highlights a stark reality. It is likely that the gaps are even higher, considering the challenges related to the definitions and monitoring of the SDGs (UN-Water, 2023). For example, a recent study of safely managed drinking water services in 135 low- and middle-income countries estimated a gap of 4.4 billion, more than double the JMP estimate in 2020 (Greenwood et al., 2024). This is largely attributed to methodology used by the study which involved geospatial mapping and household surveys (Hope, 2024).

Current data on SDG 6 targets often emphasise implementation efforts rather than the actual impact on people's lives, such as improvements to health and well-being, making it difficult to assess true progress (Stoler et al., 2023; van Puijenbroek et al., 2023). Indicators tend to focus only on microbial impacts and historical definitions of disease burden and public health challenges (Stoler et al., 2023). Discrepancies in definitions and interpretations of national and global indicators, as well as differences in methodologies for calculating and reporting data, undermine the accuracy of these estimated gaps.

Progress across the Full Cycle of WASH

The SDG WASH dataset has limited national and policy salience as it is global and has not been fully standardised. For instance, while global access to piped drinking water has increased, this does not necessarily equate to access to safely managed drinking water[4] as issues such as inadequate quantity, and intermittent supply persist (UNICEF & WHO, 2023).

From 2015 to 2022, access to safely managed drinking water has increased by four per cent, whereas access to piped water has grown by only two per cent. This highlights the significant reliance in some regions on alternative modes of supply / improved sources such as water ATMs/kiosks, borewells, packaged water etc (Garrick et al., 2019; Plappally & Lienhard V, 2013).

Data also indicate that on-site sanitation is more common than sewer connections across all regions except Europe and Northern America. Globally, in 2022, a larger share of the population used on-site sanitation facilities (46 per cent) compared to those with sewer connections (42 per cent) (UNICEF & WHO, 2023).

However, within the safely managed sanitation category, a larger share of households had sewer connections (33 per cent) as opposed to on-site systems (24 per cent), indicating significant gaps in the sanitation chain for most households with on-site systems, leading to only limited and basic access to sanitation (UNICEF & WHO, 2023). ince the 2000s, the percentage of the population with sewer connections has been rising at an average rate of 0.41 per cent per year. However, the growth of on-site sanitation systems has been even more rapid. Specifically, septic tanks have increased by 0.54 per cent per year, and improved latrines by 0.25 per cent per year. In urban areas, the share of the population with sewer connections has remained relatively stable, going from 62 per cent in 2000 to 63 per cent in 2022. In contrast, the proportion of urban residents using septic tanks rose from 15 to 22 per cent during the same period. The rise in OSS is driven by rapid urban growth outpacing sewer expansion, and its affordability and ease of implementation to meet the immediate needs of newly urbanised areas. The increase in numbers could also be due to improved data coverage and reporting in low- and middle-income countries (UNICEF & WHO, 2023)

The disparity between the coverage of containment and / or conveyance systems (OSS or sewer connections) and treatment infrastructure highlights a critical challenge in advancing towards safely managed sanitation. In 2022, 58 per cent of global household wastewater was safely treated, a modest increase from 56 per cent in 2020, with treatment rates ranging dramatically across regions, from 24 per cent in Central and Southern Asia to 86 per cent in Europe and North America (UN-Water, 2023).

While 97 per cent of wastewater is safely managed in high-income countries such as the Netherlands, only one-third of wastewater receives adequate treatment in Puerto Rico. This disparity is evident in upper-middle-income countries like Brazil (71 per cent coverage and 39 per cent treated) and Armenia (72 per cent coverage

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[4] To monitor progress by countries towards achieving this target, the Joint Monitoring Programme (JMP) has classified drinking water sources and sanitation facilities into unimproved or improved types and factored in service levels to further categorise them into 'safely managed', 'limited or 'basic. Beyond households, WASH infrastructure encompasses facilities serving schools and healthcare facilities (UNICEF & WHO, 2023).

and less than 1 per cent treated) (UNICEF & WHO, 2020, 2023). These discrepancies underscore the urgent need for improved wastewater management, enhanced monitoring, better sludge removal services, and increased investment in treatment infrastructure to meet SDG target 6.3, which aims to halve the proportion of untreated wastewater by 2030 (UN-Water, 2023; UNICEF & WHO, 2023).

4. Impact of Urban Growth on WASH Systems and Services

Increasing urbanisation is aggravating challenges for water and sanitation services in both developed and developing countries. The nature of urbanisation and its scale makes the progress on achieving SDG 6 even more challenging.

Box 1: Data Limitations

Ensuring that data on WASH progress accurately reflect ground realities is challenging, particularly when global systems do not collect data at a disaggregated level (UN-Water, 2023; UNICEF & WHO, 2023). Issues like data availability, contextual relevance, and transparency further hinder accurate monitoring and informed decision-making.

For example, although SDG 6.1.1 covers water quality and data is collected accordingly, the comprehensiveness and consistency of data reported can vary depending on the country and monitoring systems in place. Since 2017, low and lower-middle-income countries (LMICs) have made significant progress in expanding the availability of data for safely managed sanitation and drinking water, largely due to the integration of water quality testing and on-site sanitation management indicators into household surveys. This has resulted in a notable increase in both rural and urban estimates. Conversely, despite over 50 high-income countries having comprehensive estimates on water quality, fewer than 25 of these provide detailed data for safely managed drinking water across both rural and urban areas (UN-Water, 2023).

Additionally, data on WASH services is often incomplete or lacking in certain regions and for specific populations. The GLAAS 2021/2022 country survey, which covers 121 countries and territories, represents only 66 per cent of the world's population. This includes 94 per cent of the population in SSA and 86 per cent in least developed countries. Data coverage for global WASH indicators varies widely between SDG regions, with significant gaps remaining, particularly regarding components of the full cycle of safely managed water and sanitation services.

Currently, 57 per cent of the global population lives in urban areas, which is expected to increase to 68 per cent by 2050 (World Bank, 2018). From 1950 to 2018, the urban population surged from 0.8 billion to an estimated 4.2 billion, representing 55 per cent of the total global population (UN Department of Economic and Social Affairs, 2019) . This growth is attributed to four main factors: natural population increase, rural to urban migration, reclassification of rural towns into urban areas, and the expansion of urban cities by merging of neighbouring urban and rural areas (UN Department of Economic and Social Affairs, 2019).

According to the United Nations', World Urbanization Prospects (2018), Northern America (82 per cent), Latin America and the Caribbean (81 per cent), Europe (74 per cent), and Oceania (68 per cent) are the most urbanised regions. Asia follows with 50 per cent urbanisation, and Africa at 43 per cent, with the latter expected to urbanise more rapidly in the future (UN Department of Economic and Social Affairs, 2019).

It is important to note that the UN defines urban areas based on various country-specific criteria such as population thresholds, density, infrastructure, employment patterns, and city size, leading to complexities in measurement of urban areas. The highly heterogeneous nature of urban forms globally, influenced by varying geographic and socio-economic factors, adds to this complexity (Dempsey et al., 2008; Pickett et al., 2017). These complexities, along with the presence of 'rural' areas exhibiting urban characteristics can result in underestimations of urbanisation (Ritchie et al., 2024). Hence, the above numbers are likely to be an underestimation.

The challenges to WASH services due to urbanisation span across water quality and quantity, wastewater management, and overall service delivery (Kookana et al., 2020). Even without the assumed underestimation, it is evident that urban growth is outpacing cities' ability to provide adequate services and adding to the existing deficits. For example, between 2015 and 2020, SSA and Southern Asia experienced the highest urban population growth rates (4 per cent and 2.4 per cent, respectively). At current rates of urbanisation, 90 per cent of urban growth will occur in the Global South by 2050, particularly increasing the prevalence of slums in Africa and Asia (Knudsen et al., 2020). These regions are among those with the largest gaps in access to safely managed drinking water and sanitation services. For instance, the WASH access gap in India's urban slums is likely to expand, as slum populations continue to grow at 6 to 8 per cent annually, outpacing overall urban growth rate of 2 to 3 per cent per year (Swami, 2017).

While the global population living in slums decreased by four per cent between 2000 and 2018, one in four urban residents live in informal settlements as of 2020 (Knudsen et al., 2020), where the number of people lacking basic services, especially water and sanitation, continues to rise (Birch et al., 2012; Cohen, 2006). Urban poor communities lack resilient WASH systems and are highly susceptible to environmental shocks, as they are often located in vulnerable areas easily exposed to hazards like floods, fires, and landslides (UN-Water, n.d.). The irregular layouts, remote locations, limited space, and high population density of these informal settlements make expanding WASH systems challenging and expensive. These areas often lack secure land tenure, restricting governments from servicing them (Senn & Spuhler, 2014). Studies of LMICs highlighted that the uncertain land tenure, unclear legal claims, slum rehabilitation, and upgradation initiatives often impact slum dwellers' security and willingness to invest in WASH facilities and adopt toilets (Abdulhadi et al, 2024).

Additionally, high poverty rates mean residents often cannot afford improved services (Senn & Spuhler, 2014). For example, in India, about 70 per cent of those benefiting from subsidies channelled to private water connections are not poor, while 40 per cent of poor people do not receive subsidies because they do not use any public water services (WSP, 2011).

Inadequacies and inefficiencies in infrastructure and service delivery are exacerbated by rising demand and dependence on a mix of options including private informal sector and self-supply. This often leads to coping mechanisms like informal water tankers, bottled water / sachets, water carts, ATMs, open dumping of wastewater, and pit emptying services.

Apart from the growing urban population, the specific nature of urban growth also has implications on urban WASH systems. Specific factors that can impact UWC and WASH services are increases in land areas, densities, migration, and rural-urban shifts. For example, in the Goonja draining basin (Seoul) between 1975 and 2005, the shift from natural to urban landscapes (impervious ratio increased from 43 to 84 per cent) led to decreased evapotranspiration (29 per cent), increased surface runoff (41 per cent), and significantly reduced groundwater recharge (74 per cent) (Lee et al., 2010).

Even though urban land area accounts for less than one per cent of total land area, it is rapidly expanding, with low- and middle-income countries expected to drive most of this growth (UN Department of Economic and Social Affairs, 2019). From 1975 to 2020, urban land area expanded from 0.2 per cent to 0.5 per cent of the total land area and is projected to reach 0.7 per cent by 2070. Cities are expanding in land area at twice the rate of their population growth, potentially tripling global urban land area between 2000 and 2030 (Khor et al., 2022). Most of this expansion is likely to take the form of urban sprawl, significantly affecting the urban poor. This growth is expected in low-income countries, where urban land area could increase by 141 per cent compared to 44 per cent in lower-middle-income countries and 34 per cent in high-income countries, based on 2020 levels.

Without proper design, urban expansions increase impermeable areas and reduce vegetation cover. This in turn impacts water cycles through increased surface runoff, and reduced groundwater recharge. Such land use and land cover changes also lead to higher risk of flooding, altered evaporation, and degradation in water quality and ecosystems. Most urban low-income settlements are at greater risk of exposure to these hazards, as they are often located in low-lying areas or close to canals, waterways, and drains, and typically lack adequate infrastructure.

Urban settlements are also becoming denser, with varying expansion and densities across regions. Specifically, densities in low-income countries on an average have increased from 7,000 to 11,000 inhabitants per sq. km between 1975 and 2015. However, in regions like North America and Europe, where densities are lower, land area has grown much faster than the population, leading to increased energy consumption, greenhouse gas emissions, climate change, environmental degradation, and higher cost of providing infrastructure (Khor et al., 2022; Knudsen et al., 2020). Urban water and sanitation infrastructure is typically designed based on specific population densities and projected growth over its lifespan. Higher densities can lead to efficiencies, such as lower per capita energy consumption for pumping. However, if densities exceed design limits rapidly, it can result in disruptions and overflows, with substantial costs for infrastructure replacement. Conversely, when densities fall below design capacity, the required flows may be insufficient, potentially affecting system performance.

Migrant settlements in urban areas differ from older, more incremental informal settlements. The nature of work for rural-urban migrants, such as gig-economy jobs, influences their settlement location, hazard exposure, and access to services. These settlements are often temporary, crowded, and located near workplaces due to the short and seasonal nature of work. As a result, access to safe water and sanitation is inadequate, with overcrowded facilities and poor-quality infrastructure.

In addition, when rural areas are reclassified as urban, changes in land use, such as agriculture to residential and commercial, happen over a short period, which can significantly affect water quality and availability. Different institutional arrangements for rural and urban WASH services and the lack of capacity within public service providers further hinder their ability to respond to the changing nature of demand for WASH services.

In the coming decades, as urbanisation accelerates and climate change-induced shifts in precipitation patterns and damages to aquatic ecosystems intensify, the demand for resilient WASH services will become imperative, necessitating greater investment merely to sustain existing service standards (Juuti et al., 2012; Sedlak, 2019). Although economic growth is expected to improve access to basic services, overcrowding, poor urban planning, and weak institutions are likely to worsen disparities in access to basic WASH services within urban areas, especially in informal settlements (UNICEF, 2019).

5. Analysis of Status and Challenges in Water and Sanitation

The status of urban water and sanitation services worldwide point to several underlying complex challenges that must be addressed to achieve universal access. Despite the recognition that WASH has received, the current situation and trends in urban water and sanitation services suggest by 2030, billions of urban residents will still lack access to safe water and sanitation services (UN-Water, 2023). Evidence indicates that 25 per cent of water points fail within four years, and there are frequent reports of people reverting to open defecation practices, underlining that one-time investments are not sufficient, but require sustained O&M (Banks & Furey, 2016). This underscores the critical need for sustainability to prevent regression and achieve environmental goals. Additionally, since the urban poor make up a significant portion of those without access, ensuring equity and inclusion in water and sanitation services is essential.

While there is much discussion around the need for increased capital investments, the challenges in urban sanitation and water go beyond mere infrastructure investment. They include institutional barriers, financial constraints, maintenance and capacity issues, behavioural factors, inclusion gaps, and poor data and measurement. Even while most of these well-recognised challenges persist, there are new, or emerging issues that have gained attention recently. These include the inadequate focus on green infrastructure and its links to services, as well as new threats such as novel contaminants, antimicrobial resistance, and climate change.

The different areas of action are synergistic, with improvement in one often leading to improvement in other areas. For instance, strengthening of institutions through capacity and competency improvements has led to better service delivery and cost recovery (Biswas et al., 2021; Goksu et al., 2019).

This review identifies five critical action areas—institutions, technology, infrastructure, funding and behaviour change. While there are other areas, improvements in these five areas can have cascading impacts of other areas such as on data and measurement, and monitoring and evaluation.

Prioritising these specific areas helps build a broad yet systematic approach to transitioning urban water and sanitation, addressing immediate needs, and achieving long-term environmental and public health outcomes. Below, we discuss these five key areas for our analysis in greater detail.

5.1 Evolving Understanding of Institutional Arrangements and Drivers

The urban WASH system consists of a wide range of institutions and actors who play various roles—such as policy formulation, regulation, infrastructure design and implementation, service delivery, and monitoring—across different scales (city, regional/ provincial, national, and global). The UNICEF global framework classifies these institutions into government and parastatal agencies, private sector organisations, global actors, and national/ international technical specialists (UNICEF, 2019).

At the global level, financial institutions, bilateral development agencies, foundations, and the UN play crucial roles in influencing national development programmes where public investments are weak. There are also international research institutions and NGOs involved in developing solutions and knowledge dissemination (Mumssen et al., 2018; UNICEF, 2019).

National government and parastatal agencies include ministries responsible for water and sanitation policy and legal frameworks, regulatory bodies overseeing standards, monitoring, and enforcement, and government departments at various levels involved in planning and service delivery. Urban local bodies, public utilities or parastatal agencies, which may be publicly owned or structured as public-private partnerships (PPPs), often deliver services at the sub-national and local level (UNICEF, 2019). Various types of private institutions are also involved in service provisioning, with different cities adopting different formal and informal arrangements (Beard & Mitlin, 2021). The private sector's role extends to infrastructure development, technological innovation, and providing financial investment and expertise to scale up interventions across the full cycle of water and sanitation.

Private sector participation in water and sanitation services has been brought in through corporatisation of public entities and / or through direct involvement (with market competition), with the aim of enabling competition to improve efficiency and increase financial investments (Mumssen et al., 2018; OECD, 2009). Types of private organisations involved range from formal large corporations and multinational companies that operate across the full cycle of water and sanitation to informal small-scale enterprises such as water tankers, packaged water vendors, and de-sludging operators that make up for deficiencies in public services (Howard, 2005; OECD, 2009).

The formal companies engaged in both infrastructure creation and service delivery across both water and sanitation have taken the form of public-private partnerships or privatisation of parts of the service chain which involves the creation and transfer of assets or operations. The participation of private sector is characterised by some level of risk sharing between the public sector and private entities that is defined through a wide range of contractual arrangements. Examples of which include service contracts, leases, several variations of build-own-operate-transfer (BOOT) agreements, joint ventures, water co-operatives or public limited companies (OECD, 2009).

The objectives of these arrangements are to deliver better outputs in terms of increased coverage and service levels along with better financial management such as billing and cost recovery. They have also sought to catalyse more private funding and investment in the sector. While the role of private sector involvement has diversified significantly over the years (OECD, 2009), the results of their efforts have been inconclusive, with some studies showing no or limited efficiency improvements and low private investment levels relative to public expenditure (Marin, 2009; Mumssen et al., 2018).

However, the existing configuration of public and private institutions has struggled to deliver safe, equitable and sustainable urban water and sanitation services. The persistent lack of progress in this area, compounded by external drivers such as water scarcity and environmental changes, has highlighted shortcomings in formal institutional setups, often more so than in other areas of technology and financing (Barbier, 2022; Herrera, 2019).

Weak institutional arrangements (such as where there are gaps and overlaps in responsibilities, non-alignment of financial and administrative authority, poor planning, coordination and decision-making, and lack of accountability) and their suboptimal functioning are leading to inefficiencies and inadequacies in service delivery, eroding public trust in urban water and sanitation systems (Mumssen et al., 2018).

Water and sanitation systems are inherently complex, extending beyond municipal, regional, and national boundaries (Edelenbos & Teisman, 2011). This complexity is further compounded by the involvement of numerous institutions with differing, and sometimes conflicting interests—such as prioritising water quality over water provisioning. The division of responsibilities among various institutions overseeing policy, regulation, financing, and service delivery often results in a misalignment between policies framed at the national level and programmes, which are typically implemented by local and sub-national authorities (Herrera, 2019). Additionally, there is also lack of horizontal alignment of cross-organisational agendas due to entrenched departmental cultures (Edelenbos & Teisman, 2011). Siloed decision-making that neglects interdependencies, has led to inefficient and ineffective resource use (World Bank, 2020).

Institutional reliance on expert-led and top-down decision-making approaches often results in superficial engagement with local communities and stakeholders. This approach fails to leverage tacit knowledge and overlooks important socioeconomic, cultural and environmental values, leading to weak community ownership and poor sustainability of outcomes. While decentralisation of institutions is often promoted for its emphasis on bottom-up decision-making and greater community participation, it does not necessarily make a case for decentralisation in all contexts. Even when decentralisation is pursued, partial efforts that devolve administrative responsibilities without granting adequate fiscal authority limit the resources available to local institutions (Bernal et al., 2021; Herrera, 2019; Tsinda et al., 2021). Such incomplete decentralisation has hindered community buy-in and engagement in decision-making, which are essential to achieving equity and sustainability outcomes.

Inadequate resources, specifically in terms of human capacity and competency (such as the ability to challenge power bases, detect irregularities, and enforce regulations) have also often created environments conducive to corruption and other abuses of power, such as cronyism, and low tariffs in exchange for votes (Camancho, 2021; Soppe et al., 2018). Institutional capture by vested interests and perverse incentives, along with weak accountability systems, have led to the neglect of certain communities' needs (Herrera & Post, 2014; Soppe et al., 2018).

Additionally, the current institutional structures have been slow to adapt to rapidly changing conditions such as water availability and urban growth (Barbier, 2022). This sluggishness is partly due to the 'path dependency' of these institutions, established during periods of relative water abundance when innovative approaches to meet increasing demands were not necessary (Barbier, 2022).

The inability of formal institutions to deliver adequate water and sanitation infrastructure and services to all has given rise to thriving informal service providers (Evaristo et al., 2023; Garrick et al., 2019; Herrera, 2019; Zozmann et al., 2022). This review did not find a comprehensive study that quantifies the global size of informal water and sanitation services. However, evidence from several regions suggest an estimated 25 to 70 per cent of urban population worldwide could be relying on informal service providers for water and sanitation (Arias-Granada et al., 2018; Asian Development Bank, 2023; Garrick et al., 2019). Estimating the size of informal markets is challenging without a mandate for national and international monitoring systems to standardise definitions of informal services and collect data.

5.2 The Formal to Informal Continuum of Service Providers

In many LMICs, service provisioning often exists on a spectrum between formal or informal arrangements, rather than being distinctly one or the other. These arrangements can sometimes complement formal services or, in other cases, conflict with them (Garrick et al., 2019; USAID URBAN WASH, 2023). Informal providers may fill gaps across the full cycle of water and sanitation services, offering alternatives to non-existent or unreliable formal services, or act as competitors by reducing the customer base for formal systems.

Increasingly, informal service providers are recognised as critical to achieving universal access, especially in informal settlements. For example, in the Philippines, Manila Water partnered with water cooperatives to expand coverage to low-income settlements. While the utility provided infrastructure to the edge of these settlements, private service providers extended the network within the settlements and oversaw service provision. Manila Water managers trained local providers to read bulk meters and restricted them from charging more than 20 per cent of the bill amount (Asian Development Bank, 2023; Agarwal et al., 2023). In Burkina Faso, the National Office of Water and Sanitation (ONEA) extended pipelines to the edge of informal settlements and delegated construction within these areas to private informal providers, who were already operating there. This approach resulted in rapid coverage expansion and revenue growth for ONEA (Goksu et al., 2019).

Along with the total lack of formal services, inadequacy in the form of poor quality or unreliability of formal services also drives demand towards informal providers. In some cases, public utilities cannot keep pace with the rapid growth of urban areas and the high capital investment requirements, leading to co-opting of informal service providers to meet requirements in informal areas (Garrick et al, 2020; USAID URBAN WASH 2023). For example, in India, about 75 per cent of municipal tap water users receive less than the national benchmark of 135 litres per capita per day (lpcd) (Safe Water Network, 2016). The urban poor are the most severely affected, with residents in affluent neighbourhoods of large cities consuming up to 10 times more water than those in poorer areas (Babu, 2021; Times News Network, 2017). In slums, daily water supply is often insufficient, with many households using less than the World Health Organisation's recommended minimum of 50 lpcd (Safe Water Network, 2016). Additionally, water contamination levels are high, both in the water provided and in stored supplies (Safe Water Network, 2016).

Informal markets are characterised by a proliferation of small and medium-sized private providers, primarily serving informal settlements but not limited to them (Garrick et al., 2019). These markets often develop locally, with enterprises set up by residents from the areas they serve (Arias Granada et al., 2018). These enterprises offering water and sanitation products and services are highly diverse, with flexible and dynamic business models that allow them to adapt to changing contexts (Gero et al., 2014).

However, there is a persistent notion that informal service providers tend to exploit the poor, exacerbating inequality and vulnerability. While serving the poor is not necessarily a priority for these providers—due to limited economies of scale to offset the low fees poorer households can afford—there is evidence that some informal providers offer flexible pricing to enable poor households to enter the market. Yet, this remains a challenge in most contexts (Gero et al., 2014). The relatively higher prices charged by informal providers are often due to higher upfront, unsubsidised supply chain costs and the inability of households to store large quantities of water, rather than the market power of the service providers (Garrick et al., 2019; Zozmann et al., 2022).

Despite the growing importance of informal markets in expanding coverage, there is a lack of conclusive evidence on the actual quality and affordability of the services provided (Garrick et al., 2019; Zozmann et al., 2022). While consumers may perceive informal water sources to be better and are willing to pay a premium, evidence does not support this perception (Post & Ray, 2020). Certain modes of informal services may inherently lack the capacity to advance affordability and equity goals (Mitlin & Walnycki, 2020; Zozmann et al., 2022). In addition, the viability of informal markets is because of their illegality stemming from an absence of institutional capacity, which also makes it difficult to regulate these services (Garrick et al., 2019).

Yet, given the chronic delays in expanding formal services, and the urgent need to address service gaps particularly for the urban poor, it is essential to harness the burgeoning role of service providers through effective regulation and financial support as well as social protection and safety measures. Diverse modes of service delivery along with diverse technologies and infrastructure, offers cities several options to ramp up safe and resilient universal coverage.

5.3 Diversity of Technologies and Infrastructure and their Application

Infrastructure and technology[5] have played a key role in enabling and improving service provision and enhancing WASH outcomes. In LMICs like India, challenges in WASH are often attributed primarily to poor governance and socio-cultural issues rather than technologies (Government of India, 2012; Kumar, 2014).

SDG 6 explicitly highlights the role of technology and infrastructure in accelerating coverage, increasing the efficiency of WASH systems, and securing water sources. The role of technology spans across different stages[6]

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[5] Technology in this note refers to technologies for WASH infrastructure (membrane technology in treatment infrastructure), measurement (sensing), monitoring and control (IT-IOT)

[6] In this paper, stages or basic process of WASH systems refer to water extraction, water treatment, water distribution, wastewater collection and conveyance, and wastewater treatment and reuse/disposal; these are common for various types of technologies and infrastructure; in certain types of technologies and infrastructure all stages are integrated in a single system such as septic tank-soak away or renewable energy-driven water extraction-treatment units

of WASH systems, characterised by a complex landscape shaped by operational efficiencies, environmental impacts, and economic and social considerations (Soares et al., 2017; Obaideen et al., 2022).

While broadly technology and infrastructure can be classified as centralised and decentralised, there are continued debates (see Box 2) about which form is better. The choice between these models depends on factors such as land availability, population density, local governance capabilities, skills levels, and financial resources (Andersson et al., 2016; Bernal et al., 2021; Chirisa et al., 2017; Lawrencia et al., 2023).

Box 2: Centralised or decentralised systems

The debate over which system is most appropriate continues to garner attention, and that largely depends on specific circumstances (Mitra et al., 2022). For example, centralised systems are often best suited for densely populated urban areas where large volumes of wastewater can be managed effectively at lower costs. Conversely, decentralised systems are more suited for regions where such scalability is unnecessary or unfeasible (Bernal et al., 2021). Each system plays a pivotal role in the broader strategy of water and sanitation services, complementing the other by catering to different geographical and socio-economic contexts (Andersson et al., 2016; Chirisa et al., 2017; Gikas & Tchobanoglous, 2009; Lawrencia et al., 2023; Silva, 2023). Given the pace and nature of urban growth, transitioning from one system to the another must consider various factors, including the strengths and weakness of the existing systems (TNUSSP, 2018).

Despite differences, certain conditions, features and challenges are common across various technologies and stages of WASH systems.

Failures in WASH systems are often attributed to inadequate management or neglect of O&M by responsible agencies, particularly in decentralised systems (DFID, 1998; Müllegger et al., 2011). For example, in SSA, approximately one third of a million handpumps are non-functional at any given time due to poor maintenance (Andres et al., 2018). In addition, aging infrastructure is a widespread issue across all stages and different types of WASH systems (UN Water, 2017).

Measurement and monitoring are also often given low priority. The pace of technological innovation is much faster than the time needed to understand its impacts fully (Andres et al., 2018). Without adequate feedback on the impact of the technologies, decisions are made on uncertain grounds, potentially leading to adoption and scaling of inappropriate technologies and path dependence of these technologies. The effects of climate on water cycles and the emergence of new contaminants are not yet fully understood, resulting in multiple approaches to improve WASH systems (Sedlak, 2014). Addressing these challenges requires ongoing research and adaptive strategies to ensure that technologies remain effective in changing conditions.

The next sub-sections offer an analysis of existing technologies and infrastructures across the different stages of WASH systems—water extraction, water treatment, water distribution, wastewater collection and conveyance, and wastewater treatment—to highlight the adequacy and challenges.

Water Extraction

Water extraction is a crucial component of both centralised and decentralised WASH systems. Traditional water systems have long utilised diverse sources like open wells, surface water, and rainwater, tailored to local contexts with small-scale storage solutions. Innovations in drilling, plumbing, and pumping techniques brought efficiencies and access to larger sources, fundamentally changing how growing settlements sourced water. However, traditional methods continue to exist, especially in rural areas of India, Bangladesh, and China, and are even making a comeback in urban areas (Martínez-Santos et al., 2020).

Today, most large[7] cities globally rely primarily on surface water from single, large sources (McDonald et al., 2014) due to depleting groundwater and reduced availability of other local sources. Cities are increasingly focusing on rainwater harvesting for direct use and to replenish their groundwater sources. The costs of water supply through rainwater harvesting can vary significantly from USD 0.63 to USD 1.75 per cubic metre depending on the project's size (Cooley et al., 2019). Though rainwater has the potential to serve as a regular or supplementary water supply source for about 6 per cent of the global population, its potential has not been realised, mainly because storage is considered expensive (UN Department of Economic and Social Affairs, n.d.). Storage can take many forms—such as tanks (made of concrete and polymers), reservoirs, or managed aquifer recharge—and plays a critical role in ensuring that collected water is available when needed (García-Avila et al., 2023). Harvested rainwater is typically stored in tanks for non-potable uses, such as gardening or cleaning. However, at larger scales, adequate treatment infrastructure is essential to ensure that stored water can be safely used for potable purposes (García-Avila et al., 2023; Gao et al 2024). Water retention and recharge methods through infiltration pits, ponds, or aquifers provides a sustainable way to enhance water availability (Huang et al 2021). Developing cost-effective storage options and promoting their adoption will help make rainwater a more viable water supply source.

Water extraction is highly dependent on energy. Groundwater pumping is more energy- intensive than surface water pumping, except when water is imported from long distances. When designing or improving a water extraction and distribution system, it's essential to consider the overall WASH system rather than focusing only on extraction and distribution. For example, in Australia, a cost comparison of water transmission methods showed that obtaining water through local desalination was more economical than transporting it from a distant source (Plappally & Lienhard V, 2013).

To reduce energy consumption and dependency on fossil fuels, integrating energy-efficient and renewable energy sources with WASH systems is increasingly being adopted for small communities (Bamford & Zadi, 2016). While renewable energy integration has worked in small-scale WASH systems, significant challenges remain for large-scale operations. High costs of energy storage devices and space requirements are limiting the widespread adoption of renewable energy for water extraction (Hamawand, 2023; Liu et al., 2022; Murgatroyd & Hall, 2020).

Water Treatment

Water treatment systems operate at two scales: household level, commonly known as Point-of-Use (PoU) systems, and community or city scale. Despite the aspiration of many cities to have city-scale centralised system, PoU systems are gaining popularity. PoU water treatment technologies are particularly important for those without access to safely managed water, although their use is not limited to such contexts. Even in countries like the US, where more than 96 per cent of the population has access to centralised treatment systems, PoU technologies are widely used. Incidents of water contamination like those in Flint, Michigan, have heightened awareness of water quality issues, driving many to seek more control over their water safety, making PoU systems a popular choice (Lawrencia et al., 2023; Siwila & Brink, 2019; Wu et al., 2021).

Numerous PoU technologies are widely used, with many patented innovations such as filter caps (UNICEF). These systems are designed to remove both standard and emerging contaminants. PoU technologies can be as basic as boiling water, the most prevalent PoU method in Southeast Asian countries like Cambodia, Indonesia, Timor-Leste, and Vietnam, (Plappally & Lienhard V, 2013). For removing emerging contaminants like pharmaceuticals and plasticisers, technologies such as granular activated carbon, integrated membrane systems, radiation, and

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[7] McDonald et al., surveyed 50 large cities (population >750,000) and a representative sample of more than other 100 large cities

activated oxidation are available (Sharma & Bhattacharya, 2017; Wu et al., 2021). Some PoU technologies, such as ceramic filters, chlorination, and solar disinfection (SODIS), are effective against biological contaminants and can operate with low or no energy requirements.

At the city scale, the intended use or required water quality determines the appropriate treatment technology. No single technology can address all water quality issues independently; instead, hybrid technologies are often necessary. Reverse Osmosis (RO) serves as an example, where coagulation, flocculation, and disinfection are part of the treatment system, and critical to prevent fouling and reduce damages to RO membranes. However, these necessary pretreatments introduce new challenges, such as the degradation of membrane integrity through chlorination, necessitating incremental innovations such as de-chlorination, Electrodialysis-Reverse Osmosis (ED-RO) (Plappally & Lienhard V, 2013; Sharma & Bhattacharya, 2017).

Membrane-based technologies such as Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), and RO are gaining attention not just for their efficacy but also for their versatility in addressing specific water quality goals. They are likely to see innovations that reduce fouling, improve efficiency, and lower costs, with new materials and designs that enhance performance and lifespan of membranes, making them more accessible and cost-effective (Obotey & Rathilal, 2020; Plappally & Lienhard V, 2013). Desalination, while effective, requires substantial energy, often requiring over 1 kwh per cubic metre of treated water (Bredariol et al., 2024). The use of renewable energy sources in centralised water treatment systems with RO and desalination are increasingly considered for enhancing environmental sustainability (Obotey & Rathilal, 2020; Plappally & Lienhard V, 2013).

Various options are available for water treatment at different scales, and the adoption of these technologies is influenced by socioeconomic, environmental, and cultural factors, including water literacy, affordability, and indigenous perspectives, as seen in studies from Malawi and Malaysia (Lawrencia et al., 2023).

Water Distribution

Water distribution systems encompass a wide range of methods, from pipelines and canals to water tankers, bottled water, and water ATMs (Garrick et al., 2019). In SSA, diverse water supply methods cater to the needs of the ‘unconnected’ urban population. Standpipes are a primary water source for many, while household resellers significantly supplement water supply, especially in areas where formal connections are sparse. Mobile vendors play a crucial role in high-conflict or poorly connected areas, and small-scale independent providers are significant in peri-urban zones not served by main networks (Keener et al., 2010).

Currently, the operational efficiency of the water distribution through networks is very low, as evidenced by high levels of Non-Revenue Water (NRW), resulting in a global loss of USD 39 billion (Liemberger & Wyatt, 2019). Long-distance water transmission and distribution further increase the likelihood of leaks and system failures. There is a widespread deployment of technologies to reduce NRW, which are in various stages of implementation across different regions.

Table 4: Average NRW by region and countries

Region	NRW Region (average l/capita/day)	Highest		Lowest	
		Country	NRW (l/capita/day)	Country	NRW (l/capita/day)
Sub-Saharan Africa	64	Mauritius	233	Togo	11
Australia and New Zealand	36	Australia	30	New Zealand	67
Caucasus and Central Asia	152	Armenia	541	Kazakhstan	60
East Asia	42	Mongolia	91	China, Macao SAR	26
Europe	50	Montenegro	595	Netherlands	9
Latin America and Caribbean	121	Guatemala	693	Haiti	26
Middle East and Northern Africa	96	Bahrain	223	Palestine	18
Pacific Islands	211	Guam	387	Niue	9
Russia, Ukraine, Belarus	65	Ukraine	80	Belarus	56
South Asia	93	Malaysia	155	Cambodia	8
Southeast Asia	81	Pakistan	196	Afghanistan	46
United States and Canada	119	United States	123	Canada	64

Source: Liemberger & Wyatt, 2019

A critical aspect of water distribution systems is the energy consumption per volume of water supplied, along with associated costs and carbon emissions. Energy consumption varies widely, primarily due to terrain differences. For example, Loudoun, Virginia, uses 2.28 kWh/m^3 of water distributed due to its mountainous terrain, while Alexandria, with flatter terrain, uses 0.55 kWh/m^3. In Auckland, energy consumption is 0.21 kWh/m^3, while Taipei, with older infrastructure, uses between 0.26 and 0.51 kWh/m^3 (Sharif et al., 2019). There is a need to improve network energy efficiency by improving water quality, optimising pumping methods, right sizing the network, and overall comprehensive planning that accounts for various critical aspects, including terrain conditions.

Wastewater Collection and Conveyance

Wastewater collection and conveyance technologies have seen little change over time as opposed to water technologies. Traditional methods, such as using sewers and the manual or mechanical emptying of pits and septic tanks, have largely persisted, leading to a certain degree of path dependence. Conventional sewers were originally built as combined systems to manage stormwater, greywater, and eventually blackwater. These systems continue to serve large populations, particularly in developed countries. Generally, older systems or those serving smaller populations tend to be combined, whereas newer systems are usually separate (Moreira et al., 2016). Consequently, historic city centres often have a higher proportion of combined sewers, while newly developed suburban areas typically feature separate systems (Abbas et al., 2019).

However, combined sewer systems can be problematic in modern urban settings, particularly during heavy rains when they often overwhelm treatment facilities (UN World Water Assessment Programme, 2017b). Countries such as Finland (95 per cent), Portugal (>95 per cent), Sweden (88 per cent), France (68 per cent), Germany (57 per cent), Cyprus (100 per cent), and Estonia (new structures) have prioritised separate sewer systems to enhance stormwater management and reduce pollution risks associated with combining sewage and stormwater (Milieu, 2016).

Addressing and correcting existing combined sewer systems is expensive. For instance, in the US, the investment needed to address existing combined sewer overflows is estimated at approximately USD 48 billion over a period of five years (Daguillard, 2016).

Maintaining aging sewer infrastructure is another costly challenge, particularly in cities like London, where Victorian-era sewers are still in use. These systems suffer from issues like corrosion and clogging, which results in sewage spills and water contamination. Addressing these problems requires significant investment. For instance, in the US, USD 52 billion is required to address such problems (Daguillard, 2016).

Overcoming the path dependence of these systems remains a challenge. In response to the high costs associated with traditional sewerage, simplified sewer systems (SSSs) have emerged as a successful cost-effective alternative, suitable for both high- and low-income neighbourhoods. SSSs are also preferred because they enable separation and allow for the reuse of stormwater. They are typically laid in small gradients and require few or no pumping systems. For example, in Brazil, the cost per person for simplified sewerage is significantly lower than conventional systems (UN-Water, 2017). However, SSSs too present challenges such as large spatial footprints, especially in cities like those in the UK, where narrow streets already house complex utility networks (Abbas et al., 2019). Additionally, they can lead to the direct discharge of polluted runoff, which can contain heavy metals and other contaminants from streets into rivers.

Advancements in sewer system design, construction, and maintenance have prompted a re-evaluation of traditional urban drainage. Initiatives by organisations like the USEPA, including real-time control systems, vacuum sewerage, and sustainable drainage systems (SuDS), offer new ways to enhance urban wastewater management (De Toffol et al., 2007; Mannina & Viviani, 2009; Quaranta et al., 2022).

Wastewater Treatment and Reuse

Wastewater treatment technologies are shaped by the specific needs of different contexts—urban, suburban, and rural—each with distinct land availability, disposal methods, and reuse intentions. On-site systems, such as pits, privies, cesspools, cesspits, and septic tanks are the traditional methods for containing, treating, and disposing or reusing wastewater across the globe (Bond et al., 2013; Water and Sanitation Program, 2008). These traditional systems were designed for reuse and safe on-site disposal. In many parts of the world, including India, China and Japan, stabilised waste material from the pits is used as manure for agriculture purposes. While urban centres are now provided with sewer networks, the use of on-site systems remain prevalent, particularly in small cities and peri-urban areas, where Faecal Sludge Management (FSM) plays an important role in closing the loop.

The key challenges with on-site systems include increased population density, which limits the on-site disposal of liquids from septic tank systems and pits due to limited soil absorption; poor functioning of improperly built on-site systems (TNUSSP, 2018); and the limited scaling of FSM. Multiple options exist to address these challenges, such as retrofitting to improve functionality and institutionalising FSM, but these needs to be scaled (CWIS, 2023). Additionally, advancements in decentralised wastewater treatment systems, along with the production of biofertilisers from such systems, support urban farming and contribute to circular economy practices (Estévez, 2022). On-site purification techniques like permeable reactive barriers and managed aquifer recharge effectively address on-site disposal and groundwater depletion challenges (Kalmakhanova et al., 2023).

There are many traditional and innovative technologies for centralised wastewater treatment, with the Activated Sludge Process (ASP) being the most prevalent globally, largely due to its established reliability (Barbier & Burgess, 2017; Soares et al., 2017; Kalmakhanova et al., 2023). In situations where land availability is not a constraint, technologies like Waste Stabilisation Ponds (WSP) and Constructed Wetlands (CW) are preferred due to their low operational demands and high efficiency. Conversely, in land-scarce settings, systems like Membrane Bioreactors (MBRs), Sequential Batch Reactors (SBRs), and Moving Bed Biofilm Reactors (MBBRs) are favoured for their high treatment efficiencies and smaller footprint. Innovations in wastewater treatment have focused on improving equipment design, controlling fouling, and developing membranes that offer increased water flow and resistance to fouling (Kalmakhanova et al., 2023; Khurelbaatar et al., 2021; Tsagarakis et al., 2003). There is also increasing focus on the reuse and recovery of resources from wastewater, given its high energy potential (Soares et al., 2017). Innovations in treatment technologies that allow for safe and efficient recycling of wastewater for various uses will play a critical role in addressing water scarcity (Chirisa et al., 2017; Ricart et al., 2021; Yalin et al., 2023).

Nature-based Solutions (NBS) are approaches that use or mimic natural processes to offer sustainable, cost-effective, and resilient alternatives to traditional systems. NBS include the restoration of forests, wetlands, and coastal systems, urban greening, sustainable agriculture, and other ecosystem-based approaches. Cities like Singapore, Melbourne, and Copenhagen are pioneering the urban application of NBS, using green roofs, walls, and parks to combat heat islands, manage stormwater, and bolster urban biodiversity. Similarly, China's 'Sponge City' initiative employs NBS to mitigate urban flooding, showcasing large-scale environmental adaptation (UN-Water, 2018).

Summary

An overall assessment of technologies across the full cycle of WASH systems highlights the importance of enabling cities to work with multiple technology options, including the adaptation of decentralised systems for higher density areas. In scenarios of water scarcity (too little water), advanced membrane technologies, water from air, rainwater harvesting and storage, desalination, and on-site systems such as Urine Diversion Dry Toilet, composting toilet, advanced/ retrofit septic tanks with reuse capabilities could potentially address challenges. (Cooley et al., 2019) highlight the importance of reducing water use and prioritising local sources by examining California's shift toward sustainable practices and noting the economic benefits of stormwater capture and urban water conservation.

Conversely, in situations of excess water (too much water), nature-based solutions—constructed wetlands and green infrastructure—can effectively manage stormwater runoff, reduce peak flows to treatment plants, and provide additional treatment through natural processes. Furthermore, wastewater treatment plants and on-site systems must be designed or retrofitted to withstand flooding and extreme weather conditions, ensuring continuous operation during and after such events. This can include sealing OSS to prevent overflow and contamination, elevating access points, ensuring proper siting away from high-risk flood areas, and designing buildings and infrastructure with elevated structures, flood walls, and materials that are resistant to water damage.

Adopting appropriate technology options will also require leveraging advances in Internet of Things (IoT) and Artificial Intelligence (AI), which could facilitate smarter water management systems (Daniel et al., 2023; Lee et al., 2015; Shahanas & Sivakumar, P. B , 2016; Yasin et al., 2021).

While technologies contribute to more sustainable practices, they fall short of completely solving the problems of water scarcity, excess water or contaminated water. This underscores the need to ensure that the planning, financing, management, governance aspects of WASH systems are oriented towards urban water conservation through reduced consumption, efficient use and prioritisation of local water resources.

5.4 Cost Assessments for Service Provision, and Recognising Funding Challenges and Evaluating Gaps

It is well acknowledged that meeting the targets of SDG 6.1 and 6.2 by 2030 requires not only increased funding but also more effective funding strategies. A critical challenge in optimising the allocation and utilisation of financial resources for WASH systems has been the accurate and comprehensive assessment of costs of services across the full cycle and over the long term.

Costs Estimates of WASH Systems

Several studies have attempted to quantify WASH costs, including capital expenditures, capital maintenance, and recurrent expenses, at different scales and for different contexts. The most recent World Bank data, covering 113 countries, estimates WASH costs to be nearly USD 210 billion annually (in 2017 constant prices) (Joseph et al., 2024). Another study assessing infrastructure gaps estimates that meeting the SDG targets (6.1 and 6.2) by 2030 in LMICs will cost between USD 171 billion and USD 229 billion. When operation and maintenance expenses are included, this figure rises to USD 406 billion to USD 509 billion, equivalent to approximately 1.1 per cent to 1.4 per cent of LMICs' GDP (Rozenberg & Fay, 2019).

Other studies have identified and evaluated key parameters that influence system costs in different contexts. These parameters include population densities, size and degree of centralisation, economies of scale, institutional and managerial arrangements, technology, labour costs, and various geophysical factors (Daudey, 2018; Libey et al., 2020; Manga et al., 2020). For example, a study in South Africa found that for population densities below 112 persons per hectare, simplified sewerage was more expensive than on-site sanitation options. This higher cost was associated with the maintenance of pumping stations and monthly household surcharges. However, for population densities above 198 persons per hectare, sewerage became cheaper than on-site sanitation options due to economies of scale (Manga et al., 2020).

Table 5 illustrates the range in cost estimates based on two studies on urban sanitation, highlighting the impact of methodological and contextual differences. The study by (Sainati et al., 2020) draws on data from 25 cities in 10 countries to calculate the Total Annualised Cost per Household (TACH) for sewerage systems. In comparison, the Boston Consulting Group (BCG) study provided per capita costs based on extensive secondary analysis and interviews with WASH experts in developing countries (Carins-Smith et al., 2014).

Table 5 Costs of sanitation systems based on different estimation methodologies

	Total costs (capital and operating)	**Capital costs**	**Annual operating costs**
*Unit**	*Int$ 2018 / household / year*	*$ / person*	*$ / person / year*
Source	*(Sainati et al., 2020)*	*(Carins-Smith et al., 2014)*	*(Carins-Smith et al., 2014)*
On-site septic tanks-based system	81 – 267	105 – 155	4 – 10
Decentralised simplified sewer-based system		70 – 360	4 – 12
Container-based sanitation	189 – 309	N/A	N/A
Centralised conventional sewer-based system	513 – 1,192	220 – 940	12 – 28

*Costs are presented in different units and do not consider service life due to the varying methodologies used in the studies. They are provided solely to illustrate the complexities involved in estimating and comparing costs

(Sainati et al., 2020) evaluated on-site sanitation technologies, including container-based sanitation with mechanised emptying, transfer stations, and composting (aerobic treatment), as well as on-site ‘septic’ tanks with mechanised emptying and anaerobic treatment. The focus of (Carins-Smith et al., 2014) was primarily on septic tanks, considering factors such as septic tank sizing, permeability and charges for conveyance and disposal based on distances. (Sainati et al., 2020) considered factors such as land rental, salaries, administration, and public concession costs to account for annual operating expenses.

Although the costs outlined above aim to be comprehensive, these figures may not fully account for the expenses related to aging infrastructure, which will need replacement, or the additional costs related to climate change adaptation. The estimated costs for safely managed water and sanitation services may also overlook the higher costs of last-mile service delivery, particularly for reaching vulnerable populations. Achieving inclusivity outcomes, such as occupational health and safety and social protection for sanitation workers, also may not be reflected in these figures.

There are several challenges in capturing these nuances and arriving at a realistic estimate of costs for the service provided. These includes difficulties in clearly disaggregating costs over the lifecycle of water and sanitation systems, linking them to service levels, and factoring in adaptation expenses related to emerging climate change challenges (see Box

Box 3: Challenges in Estimating Costs for Water and Sanitation Systems

The literature identifies several challenges in urban water and sanitation cost reporting. These include underreporting, more so in sanitation than water, and inconsistencies in the methodologies used for reporting (Daudey, 2018). Additionally, there is a lack of a comprehensive and reliable global database that provides cost data estimated using standardised approaches (Daudey, 2018). This gap hinders the development of benchmarks for unit costs, which are necessary for making cross-geographic and cross-technology comparisons, for planning and directing investments, and facilitating effective decision-making and initiative development (Daudey, 2018).

A key limitation of cost estimates is the absence and inadequacy of data on non-networked water and sanitation services—both formal and informal—such as water tankers, bottled water supply, Water ATMs/kiosks, and cesspool trucks. Other significant drawbacks include the lack of reporting on operation and maintenance costs as well as on the costs of climate adaptation (Joseph et al., 2024). While these estimates are critical for estimating funding gaps at the global, national, and sub-national levels, efficient resource allocation and informed decision-making require disaggregated cost data. Understanding specific cost components of water and sanitation services is crucial (World Bank, 2019).

The variation in costs by region and within countries, arising from factors such as differing policies and approaches to technology upgrade and / or global macroeconomic conditions, poses significant challenges for providing recommendations on financing and implementation at the global level. For example, while SSA would require about USD 78 billion per annum between 2017 and 2023 to achieve SDG 6.1 and 6.2, Europe and Central Asia would need USD 8.8 billion, Latin America and the Caribbean USD 24.4 billion and South Asia USD 41 billion (Joseph et al., 2024). Compounding these challenges is the variability of data quality across different contexts, differences in lifespans of technology / infrastructure systems, and differences in service levels delivered by the different systems. Few systematic attempts have been made to evaluate the relationship between these parameters and costs based on empirical data at the necessary scale. Consequently, results often remain context-specific or based on models that have not been empirically validated.

A recent World Bank assessment of global spending in 130 countries estimates that nearly USD 165 billion (2017 constant prices) is spent annually in the water sector, including water supply and sanitation (WSS), irrigation, water transport, and hydropower. Water supply and sanitation accounts for more than half of the total spending (USD 141 to 153 billion, excluding official development assistance), with estimates ranging from about USD 80 billion to 91 billion per annum (2017 constant prices). Data from 69 countries showed that annual spending on drinking water was higher, at USD 31 billion, compared to USD 24 billion for sanitation (WHO/GLASS, 2022). The majority of the water and sanitation spending is directed towards capital expenses, estimated between USD 61 billion and USD 70 billion (2017 constant prices) (Joseph et al., 2024).

Regionally, East Asia and Pacific (including China) is the highest spender in water and sanitation, accounting for nearly 50 per cent (USD 40-41 billion) of the total. Meanwhile, SSA has seen the highest increase in spending over recent years. Despite an increase in water and sanitation spending in SSA from USD 99 to 116 million between 2017 and 2021, access to safely managed water and sanitation services remains the lowest among all regions. Spending on water and sanitation as a proportion of GDP remains small, ranging from 0.53 per cent in Middle East and North Africa to 0.14 per cent in South Asia (Joseph et al., 2024). In comparison, health expenditure as percentage of GDP ranges from 5.7 per cent in Africa to 8.7 per cent in Europe (World Health Organization, 2022).

The public sector, including state-owned enterprises, is the largest contributor to water sector spending, accounting for 92 per cent of the total. However, water sector spending represents only 1.2 per cent of total public spending on all human development sectors. In contrast, sectors such as education, health, and social protection receive nearly 60 per cent of the total public spending (Joseph et al., 2024). Of the total public spending in the water sector, 76 per cent is allocated to water supply and sanitation (Joseph et al., 2024).

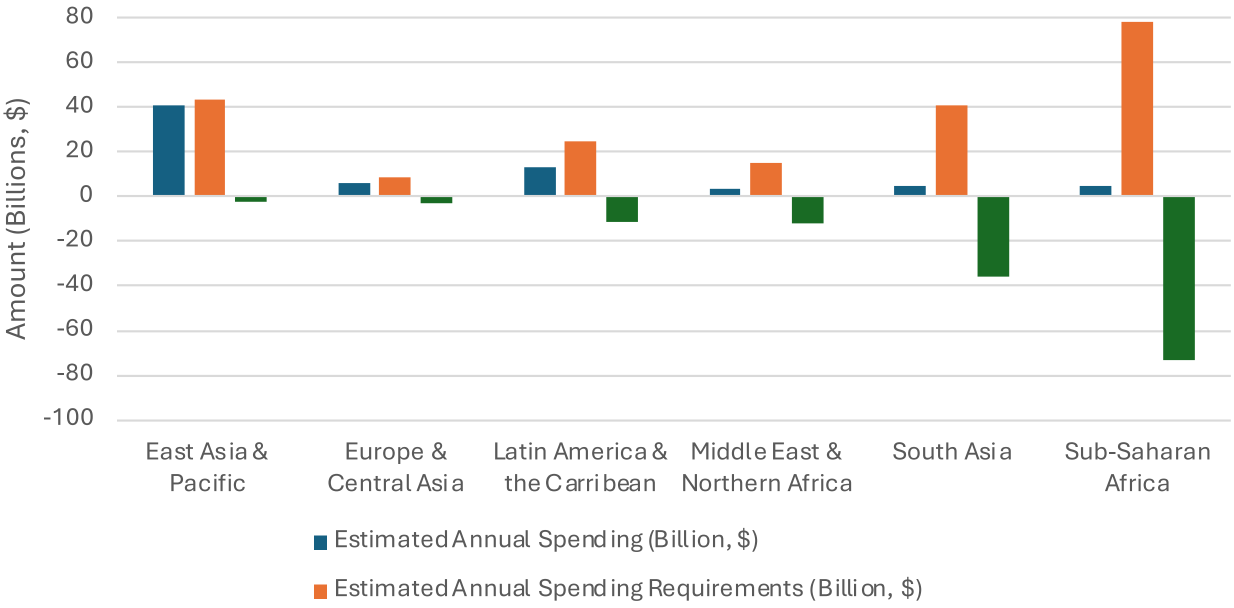
Within the water supply and sanitation sector, 80 per cent of the spending on infrastructure came from public entities (national and local governments), 11 per cent from state-owned enterprises, and about 9 per cent from the private sector (Joseph et al., 2024). These figures, however, likely exclude direct household spending, particularly on informal services. According to the Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) report (2022), 44 out of 121 countries, with a total annual WASH spending of USD 66.9 billion, reported that households were the largest source of funding at 61 per cent followed by government at 29 per cent, external sources 4 per cent and repayable finance at 6 per cent for the period from 2018-2022 (WHO, 2022).

Spending Requirement and Challenges

Globally, the levels of spending, specifically public spending, on water and sanitation services need to increase substantially to achieve SDG 6.1 and 6.2 by 2030. The required annual spending is estimated at nearly USD 210 billion (in 2017 constant prices), with operations and maintenance accounting for 54 to 58 per cent of the total (Joseph et al., 2024).

The highest spending requirements are in the SSA (USD 78 billion) and East Asia and Pacific (EAP) regions (USD 43 billion). However, the largest spending gaps are in SSA (USD 74 billion) and South Asia (SA) (USD 36 billion). Excluding India, the annual spending gap in South Asia significantly decreases to approximately USD 10.8 billion (Joseph et al., 2024).

Figure 3: Estimate Annual Spending, Spending Requirement and Spending Gap by Region



Source: (Joseph et al., 2024), 2017 constant prices

According to the GLAAS survey, key reasons for spending gaps include insufficient allocations to expand services and inadequate operations and maintenance, leading to higher capital renewal costs (WHO/GLAAS, 2022). Existing services are at a risk of deterioration and failure due to the significant challenges countries face in recovering costs (Garrick et al., 2019).

Low cost-recovery rates are a significant contributor to spending gaps. Only 35 per cent of the utilities in the International Benchmarking Network (IBNET) database can fully cover their operations and maintenance costs, and an even smaller share, 14 per cent of all utilities, can cover their total financial costs, including capital and O&M (Andres et al., 2019).

Another important factor contributing to spending gaps is poor budget utilisation (Joseph et al., 2024). The global average budget execution rate in the water sector is currently 73 per cent, driven primarily by low rates in the water supply and sanitation subsector, which are like those in the broader water sector. In contrast, the human development sector, which includes social protection, education, and health, has the highest average execution rate at 99 per cent (Joseph et al., 2024).

The low utilisation of funds is attributed to several factors, including low absorptive capacities, inadequate governance, and poor project planning and implementation. Underlying causes include inadequate human resource capacity and lengthy project implementation timelines, which average between six and 15 years (Joseph et al., 2024).

In addition to the size of spending gaps, the population segments affected by these gaps are a critical concern. A significant issue is the allocation of subsidies, which constitute a substantial portion of government spending, especially in developing countries. However, according to a study by Andrés et al. (2019), in 10 developing countries, an average of 56 per cent of subsidies is captured by the wealthiest 20 per cent of the population, while only six per cent reach the poorest 20 per cent. In developing countries where spending is already limited, poorly targeted subsidies exacerbate gaps for those most in need of funds (Andres et al., 2019; Joseph et al., 2024).

5.5 Recognising Factors Influencing Social and Behaviour Change

In Social and Behaviour Change Communication (SBCC) initiatives, identifying the specific behaviour to be modified, and the target population is key to starting interventions (Mosler & Contzen 2016). Water-related behaviours include sourcing water from safe locations, safe storage, and point-of-use disinfection of drinking water, while sanitation-related behaviours range from avoiding open defecation to proper emptying, maintenance and use of sanitation structures. While most behaviours, such as toilet use, are relevant to all stakeholders, responsibilities for tasks like safe storage of water, proper emptying of sanitation structures and point-of-use disinfection of drinking water may vary based on individual roles within the household or community. Thereby, identifying the appropriate target groups, such as women, men, children, vulnerable population, head of households, or community leaders, is crucial (Mosler & Contzen 2016).

There are different approaches to SBCC in water and sanitation that have been practised, such as water and sanitation messaging, psychosocial models, social marketing techniques and community-based approaches (De Buck et al., 2017). As a part of these approaches, there are several interpersonal, household level and external factors that influence behaviour change in the water and sanitation sector (Saurí, 2013).

The water and sanitation messaging approach uses a directive, one-way educational approach to enhance individuals' knowledge and skills to ensure better outcomes. The approach provides communities with evidence and data around water quality and safe treatment/handling practices that can help to overcome key knowledge barriers (UNICEF, 2023). In 1997, Bogotá, Colombia faced a water shortage and the government's initial emergency warning caused increased water consumption and hoarding. To counter this, the city educated residents on water conservation practices, shared daily consumption data, highlighted cooperative behaviour, and featured the mayor in a TV ad promoting water-saving techniques which led to lasting water use reductions (World Bank, 2015).

However, several studies have highlighted that while informativeness is an important factor in promoting behaviours, they may not always translate into behaviour change (Saurí, 2013). This is addressed in the psychosocial approaches which focus on factors other than knowledge such as emotional appeal, nudging, behavioural influencing and social pressure through various models (e.g. Integrated Behavioural Model (IBM-WASH), and Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS)) to promote behaviour change and close the knowledge action gap (Bakar et al., 2021) (UNICEF, 2023). For example, in Khulna, Bangladesh, it was identified that along with appropriate education, preference groups that the target community emulates, such as celebrities, local leaders and early adopters, were required to clarify expectations and incentivise the target population to adopt proper sanitation practices (Cookey et al., 2020).

While in the above example social pressure from community leaders with regular follow-ups and messaging led to rapid sanitation improvements, studies have shown that emotional and social pressure techniques can also be ineffective at times. A study in urban slums of Bangladesh used a mix of psychosocial and social marketing approach that involves promoting water and sanitation products and services using consumer-driven strategies. The mixed approach was used to understand the impact of emotional pressure messages and social marketing techniques on water chlorination use among residents. The study highlighted that disgust-and-shame messages did not significantly increase chlorination use for water treatment or willingness to pay for chlorine after a free trial ended. The qualitative household interviews from the study revealed that the feelings of disgust faded over time, and social concerns were low and one of the possible reasons for low uptake of disgust-and-shame messages was due to the poor reach of these messages to men (reached only 20 per cent of the male population) who were socially more influential in Bangladesh culture than women (Guiteras et al., 2015). In terms of social pressure and shaming, recent discussions in global health emphasise that it should not be used to promote better health outcomes, as it can cause psychological harm, particularly among low-income households that cannot afford necessary changes (Nelson et al., 2021). However, the social marketing component of the same project in urban slums of Bangladesh which was provisioning free supply of soapy water bottles showed a modest increase in handwashing, highlighting the greater influence of price over promotion or education (Guiteras et al., 2015).

This indicates that approaches requiring significant financial investments or efforts have been found to be less effective. A study of 248 urban households in India revealed that water conservation behaviours such as reusing wastewater from filtration systems or installing water-efficient dual-flush toilets, were less popular. In contrast, simpler actions with no financial cost, like turning off the faucet while brushing teeth or washing dishes, were easily adopted by nearly 94 per cent of households (Ramsey et al., 2017).

Hence financial factors have a significant impact on SBCC approaches. For example, an imposition of water prices and taxes worked as an effective complementary instrument for water conservation messaging and marketing approaches in Spain. In Zaragoza, Spain, there was a reduction of 5.6 per cent in water consumption after one year of a water awareness programme combined with higher prices (Saurí, 2013) .

Additionally, there have also been examples of success of certain water conservation programmes when linked to previously experienced instances of water stress. When assessing the impact of public information campaigns on water conservation in four large regions of the US (northeast, north central, southern, and western), it was found that water consumption declined only in the West and not in the other areas, which as a rule did not suffer water scarcity (Saurí, 2013). Similarly, in Tehran, Iran, urban households were more likely to adopt water conservation behaviours when i) they saw water scarcity as a serious health risk, ii) felt the benefits of saving water outweighed the barriers, iii) they receive constant reminders, and iv) were ensured of self-efficacy for sustaining actions (Shahangian et al., 2022).

In the sanitation sector, community-based approaches, such as Community Led Total Sanitation (CLTS) and Participatory Hygiene and Sanitation Transformation (PHAST) are popular participatory methods to engage communities to improve sanitation practices (De Buck et al., 2017). These are considered highly effective as when neighbours improve their sanitation practices, households also benefit from the improved environment, a concept known as 'herd protection' (USAID, 2021). The Indonesia Urban Water, Sanitation, and Hygiene (IUWASH) project employed the CLTS model to improve urban sanitation in 54 cities where communities were less cohesive, and sanitation systems more expensive. The project introduced initiatives like community exchange visits to inspire action and foster peer learning. Training programmes and exposure visits for sanitation entrepreneurs aimed to build local capacity, while microfinance schemes were developed to make sanitation more affordable for households. Promotional materials emphasised the social status and security benefits of improved sanitation to further motivate communities. These interventions, addressing technical, institutional, and financial challenges along with promotional techniques, helped 2.5 lakh people access improved sanitation, with 1 lakh receiving WASH-related training (Myers et al., 2018).

Successful CLTS campaigns, have highlighted the importance of addressing multiple enabling conditions to influence behaviour change. In another instance, a project in Gulariya Municipality, Nepal (2014-2016), aimed to achieve Open Defecation Free (ODF) status through community engagement, training and institutional strengthening. Key elements included orienting Ward WASH Coordination Committees and training influential community members, with a strong emphasis on women's groups participation. Institutional alignment with government frameworks at the start of the project was crucial for sustainability. The project resulted in over 5,385 individual toilets, 319 institutional toilets, and five public toilets and achieving ODF status in 11 wards within six months. A significant lesson learned was that integrating CLTS with household-centred approaches which focused on institutional processes proved more effective in diverse urban settings. Similarly, a pilot initiative in eight Ethiopian towns where community built their own toilets reinforced that urban CLTS success relies on government commitment and leveraging existing governmental platforms for sustained interventions (Myers et al., 2018).

As part of the enabling conditions, monitoring is a key aspect of sustaining SBCC interventions and can be carried out in various ways, such as reporting, verifications, and follow-up visits. A project in Fort Dauphin, Madagascar, used household competitions to improve toilet cleanliness, with health volunteers and neighbours rating latrines based on agreed criteria. Monthly rankings were displayed publicly, and families maintaining high standards for three months received incentives, promoting positive behaviour change (Myers et al., 2018). Similarly, India's Swachh Bharat Mission (SBM) promotes sanitation through an annual survey, the Swachh Survekshan, which ranks urban areas based on cleanliness, sanitation, and waste management. The rankings, based on municipal data, inspections, and citizen feedback, are publicised to encourage competition and motivate cities to improve service delivery. The Survey, launched by the Ministry of Housing and Urban Affairs (MoHUA) in 2016, has grown into the world's largest urban cleanliness survey, covering over 4,416 Urban Local Bodies (ULBs) and gathering feedback from nearly 15.9 million citizens (Government of India, 2023).

However, monitoring interventions have several downsides, including high costs, time and resource demands, potential reactivity from subjects, and the possibility of inaccurate reporting. Monitoring can also disrupt household and community routines. Despite these challenges, prioritising monitoring remains crucial for the sustainability of WASH interventions (Nelson et al., 2021).

The examples above demonstrate that SBCC can be effective when factors like socio-economic status, self-efficacy, and attitudes are considered and neglecting factors such as cultural contexts and price can result in less favourable outcomes. Additionally, urban areas are heterogeneous and characterised by presence of more migratory population, leased properties, dense areas, rigid institutional frameworks and varying occupational roles which can also influence SBCC interventions.

6. Accelerating the Urban Water and Sanitation Transition

Cities need to shift their focus from merely increasing water supply to emphasising efficient use and, where appropriate, recycling and reuse of used water, even in regions of relative year-round water abundance.

Achieving this requires a re-evaluation of traditional urban and infrastructure planning assumptions (Sedlak, 2019). Planning decisions must prioritise the sustainable use of water by integrating natural resource management into development plans. Given the connections between peri-urban and urban agriculture, ecosystems services, biodiversity conservation, and water availability, it is essential to link land use and land cover change decisions to water availability, use, and quality. Urban land use and land change decisions often drive master planning and real estate investment processes. The integration of water-related service delivery objectives into these processes, is becoming increasingly crucial to ensure equitable outcomes, especially for the urban poor.

Urban areas are learning laboratories to thoroughly test options against the range of urban challenges and develop innovative approaches that strengthen the enabling environment. This can help scale solutions, ensuring their sustainability and resilience. To address both deep-seated, structural issues and emerging challenges in urban water and sanitation service delivery, a spectrum of approaches ranging from incremental changes to disruptive innovations across technology, institutions, and finance are required.

This review concludes by discussing a few of the key elements essential for transitioning urban water and sanitation systems.

6.1 Building, Sustaining and Adapting Infrastructure

Given the pace and nature of urban growth, selecting an appropriate mix of centralised and decentralised systems is crucial in enabling innovation to scale in respond to local conditions (TNUSSP, 2018) and addressing emerging challenges.

In areas challenged by water scarcity (too little water) a range of technical options have been proven across the world, including advanced membrane technologies, rainwater harvesting and storage, desalination, and on-site systems water recovery systems such as Urine Diverting Dry Toilet, composting toilets, retrofitted septic tanks that enable reuse. However, there is a particular challenge in inadequate water storage infrastructure—whether physical (such as tanks, reservoirs, or cisterns) or natural (such as managed aquifer recharge systems)— that limits many communities' ability to adapt to climate variability and prolonged droughts. Addressing this challenge requires integrating technological innovations like stormwater capture, urban conservation, and decentralised recovery systems to enhance local water resilience and reduce dependency on external sources, as demonstrated by California's shift toward sustainable water practices (Cooley et al., 2019)

In areas challenged by excess water and flooding (too much water) nature-based solutions such as constructed wetlands and green infrastructure can manage stormwater runoff, reduce peak flows to treatment plants, and provide additional treatment through natural processes.

Wastewater treatment plants and on-site systems must be designed or retrofitted to withstand flooding and extreme weather conditions, ensuring continuous operation during and after such events. This can include sealing OSS to prevent overflow and contamination, elevating access points, and ensuring proper siting away from high-risk flood areas, designing buildings and infrastructure that can withstand flooding through elevated structures, flood walls, and materials that are resistant to water damage.

Enabling cities to work with multiple technology and infrastructure options, including making decentralised systems work effectively in high density urban areas, is important. Advances in IoT Internet of Things (IoT) and Artificial Intelligence (AI) can enable smarter water and wastewater management (Daniel et al., 2023;Lee et al., 2015; Shahanas, K. M., & Sivakumar, P. B , 2016; Yasin et al., 2021).

Recalibrating Demand and Reviving Local Supply

The primary mandate of service providers is often to supply more water, which has led to a prioritisation of large infrastructure projects and a political economy centred around water distribution, rather than universal, efficient and affordable service delivery (Shambaugh & Joshi, 2021). Given the current deep challenges around the UWC, cities should rethink traditional supply-centric approaches and explore options to reduce consumption and enhance efficiency rather than increasing their reliance on importing surface water and unsustainable extraction of groundwater.

Achieving this requires a thorough understanding of demand dynamics and the implementation of systematic and proactive demand-side measures, such as increasing use-efficiency and implementing disincentives for excessive per capita use (Shambaugh & Joshi, 2021). Long-term fixed benchmarks for municipal supply and wastewater treatment, which often overlook downstream requirements, should be reconsidered and optimised to ensure adequate supply to all.

This shift would also require decreasing dependency on external water sources. A combination of approaches could be employed, such as revisiting and reviving traditional methods of rainwater harvesting, along with reuse of treated wastewater, and improving stormwater management. Over time, practices like rainwater harvesting and operating septic tanks have taken a back seat due to the convenience of connecting to centralised networks, reinforced by entrenched institutional and technological path dependencies. However, with technological innovation and a deeper understanding of urban water and sanitation systems and the economics of network operations, traditional systems are increasingly being reconsidered in many contexts. If viable, this approach should be encouraged further (Hosagrahar et al., 2021; A. Sharma & Ji, 2024).

There are several innovations in treatment technologies that allow for safe and efficient recycling of wastewater for various uses (Ricart et al., 2021; Yalin et al., 2023; Chirisa et al., 2017). For instance, aerated wetlands, recommended for their high-efficiency and compact design, are ideal for urban settings, promoting the reuse of treated wastewater to close the urban water cycle loop (Nivala et al., 2020).

Stormwater management in a changing climate is a critical challenge, as it intersects with urban expansion and densification, hardscaping and transportation infrastructure planning. Effective stormwater management and urban flood management require coordinated efforts by multiple stakeholders to ensure service delivery is aligned with urban development strategies.

By effectively deploying green-blue-grey infrastructure, cities can separate stormwater from sewage, and address other waste streams, including new contaminants. This would increase the availability of clean water by replenishing local sources. This can be augmented by the reuse of treated wastewater at scale, as demonstrated effectively by Singapore (Quentin Grafton et al., 2023). With sufficient technology options available, a future focus should be on addressing behavioural and perception barriers.

Improving Use Efficiency

Improving efficiency in water supply is vital to address the inequitable use of water and reduce use of potable water for non-potable purposes. There is a need to explore ways to make decentralised systems viable in high-density urban areas. This can be achieved by retrofitting on-site and decentralised systems using advances in technology, automation, information technology and IoT (CWIS, 2023). By creating networks of these decentralised systems, local reuse and service provision can be scaled effectively. The potential for decentralised sources to contribute water to reuse networks where needed can be further explored, to enhance the resilience and efficiency of current water supply system.

As urban water distribution network expands, the need for scalable and efficient networks is important to conserve water and minimise economic losses. Therefore, improved network planning and management, assisted by advanced monitoring technologies are needed for reliable water supply. In addition, dual water distribution systems for potable and non-potable water can enhance water efficiency and reduce the volume of water treatment to potable standards.

There is also a need to improve network energy efficiency by limiting losses and exfiltration, improving water quality, pumping methods, network sizing, and improving the responsiveness of planning to terrain and ground conditions.

6.2 Strengthening Institutions

Strong institutions are pivotal to successful transitions (Goksu et al., 2019b; Herrera & Post, 2014; Mumssen et al., 2018), as they are central to creating an enabling environment, without which other interventions are less likely to take hold. Chronic system failures as well as crises such as water borne disease outbreaks and severe disruptions to drinking water supply have often been catalysts for institutional change (Goksu et al., 2019). During such events, heightened awareness and agency among citizens have driven demands for improved water and sanitation systems, compelling politicians and leaders to take cognisance of institutional failures. These crises have sometimes sparked sector-wide reforms encompassing policy, institutions, and regulation (Bertoméu-Sánchez & Serebrisky, 2018), which hinge on common principles of transparency, accountability, and participation (Camancho, 2021; Goksu et al., 2019; Mumssen et al., 2018). Understanding the pathways taken during crises and as preventive measures is crucial, as it may allow for certain conditions to be replicated to bring about the necessary shifts, even in the absence of emergencies.

While there is no one-size-fits-all institutional structure, below are a few key approaches to enhancing the effectiveness of institutions.

Addressing the Political Economy

Strong political commitment is essential for sustainable transitions of urban water and sanitation systems. High-level political leadership, government champions, and incentivised and competent managers play a vital role in safeguarding reforms from political interference (Biswas et al., 2021; Goksu et al., 2019).

To counter the political economy and the power of vested interests, institutional structures need to be agile and adaptable to changing circumstances. This includes shifting the type and scale of institutions when needed (Garrick et al., 2019) to improve governance, ensure regulatory compliance, and foster competent management. For instance, when incentives are not aligned with overall sector goals, employees of institutions sometimes prioritise personal or political goals instead, undermining institutional effectiveness (Goksu et al., 2019). Additionally, local communities and citizens must actively exercise their right to safe water and sanitation to drive political commitment and raise the bar on leadership.

Mandating Responsibility while Strengthening Advocacy, Incentives, and Competencies

Effective governance for sustainable water and sanitation outcomes are not determined by whether institutional structures are centralised or decentralised. Decentralisation is not always the most appropriate or necessary option for every context. While decentralisation in certain contexts can help insulate service providers from political interference and conflicts, its success depends on the devolution of financial authority and human resource capacity to local governments (Bernal et al., 2021; Herrera & Post, 2014; Tsinda et al., 2021).

For effective governance, decisions should be made by relevant authorities with adequate resources and a significant stake in positive outcomes (Herrera, 2019; Tsinda et al., 2021; World Bank, 2020a). It is essential to assign clear roles and responsibilities to institutions at local, regional, and national levels to achieve better water and sanitation outcomes (Herrera, 2019; Tsinda et al., 2021; World Bank, 2020a). This includes integrating local priorities at all levels of government, for which there is need to strengthen capacity of public and opinion leaders to influence politicians (Herrera, 2019; Tsinda et al., 2021; World Bank, 2020b). For instance, in Tamil Nadu, India, strengthening of the full chain of FSM as a viable standalone as well as complementary solution to networked sanitation was originally not on the government agenda. FSM was championed by government officers whose buy-in and commitment was fostered through orientations and exposure visits to successful FSM sites under the Tamil Nadu Urban Sanitation Support Programme (TNUSSP, 2021).

Strong leadership and champions have been crucial to successful institutional turnarounds in cities like Phnom Penh and Manila. However, the sustainability of these transitions can be short-lived without adequate capacity at all levels of the institution (Trimmer et al., 2022). Internal capacity building and incentivising performance has been the first crucial step in most reform programmes (Goksu et al., 2019). For example, the Phnom Penh Water and Sanitation Authority's (PPWSA) initiated reforms by streamlining workforce functions through education (training programmes) and motivation (promotions, higher salaries, and incentives) (Biswas et al., 2021; Goksu et al., 2019).

Capacity development should include the professionalisation of service delivery through investments in human resources and regulatory frameworks to enhance service levels to achieve better public health outcomes and tackle complex challenges (Howard, 2021). Improved capacity and competency have been shown to improve operational and financial efficiencies of institutions (Goksu et al., 2019).

Strengthening institutional capacity requires promoting education and training of professionals (public, private and communities), along with fostering co-operation and knowledge-sharing among all stakeholders.

Facilitating Community Ownership through Trust Building

The integrity of urban water and sanitation institutions, as well as the sustainability of the services they provide, depend on local communities holding these institutions accountable. Citizens must not only have access to grievance mechanisms related to poor service delivery but also be integral to the planning process. To achieve this, expert-driven methods should be replaced with collaborative approaches that actively involve and empower local communities (Barrington et al., 2021) and build trust. In addition, institutions should adopt decision-making processes based on the actual socioeconomic, cultural, and environmental costs and benefits of water and sanitation systems. Incorporating multidisciplinary perspectives and co-produced knowledge can make decisions more holistic, sustainable, and culturally sensitive (Barbier, 2022; Garrick et al., 2020; Ricart et al., 2021; Shields et al., 2022).

It is crucial to ensure that decision-making processes and forums are not dominated by elite interest groups. These processes should be structured to account for the constraints faced by the urban poor, such as lack of time, and enable participation from all communities and stakeholders. This shift will promote ownership, better integration of local knowledge, and more sustainable outcomes (Shields et al., 2022). With greater involvement of citizens, coupled with improved services, trust between service providers and citizens improves, allowing for better acceptance of key institutional reforms such as tariff increases or other cost recovery measures.

6.3 Reshaping Service Delivery by Strengthening Informal Services

A combination of formal and informal service arrangements is essential to ensure universal services and access to water and sanitation. Hence, it is essential to improve service levels and affordability of both formal and informal services (Trimmer et al, 2022). Informal services are widely recognised to play a crucial role in bridging service gaps, in public systems, which have the primary responsibility for service delivery (Garrick et al., 2019; Joseph et al., 2024).

This potential is demonstrated by models in Kisumu, Kenya; Manila, Philippines; South Mozambique; and Lusaka, Zambia. These models have transitioned completely from unregulated or informal services to 'facilitated' or 'managed' services demonstrating improvements in coverage and some impact on affordability and service levels (Agarwal et al., 2023).

A shift to a graduated model of provisioning can be facilitated through the creation and strengthening of regulation that does not disrupt functioning business models or push service providers to find ways to subvert regulation. Light-handed regulation that reduces financial disincentives, prevents rent-seeking while simultaneously addressing oligopoly and informational asymmetry and promoting safe services could be a viable alternative, especially in contexts with low institutional capacity and limited enforcement capacity (Gero et al., 2014). For example, in Tamil Nadu, India, the government opted to retain a regulated form of the existing on-demand de-sludging service delivery system along with introducing alternate approaches where the market had 'failed'. The decision was driven by the state's intention to leverage private sector delivery through private operators by not disrupting functioning business models through price-setting interventions. The state focused on reducing financial disincentives and introducing light-handed regulations such as a Standard License Agreement for Private Operators (TNUSSP, 2019).

Prospects for growth and assurance of business continuity and resilience, which are important to informal service providers can be enabled through access to credit along with business and technical skills development (Gero et al., 2014).

6.4 Increasing and Redirecting Financial Resources

Increasing Funding and Improving Financial Management

It is necessary to increase funding through higher budget allocations. Funding should be allocated to enhance service levels and increase resilience to changes in ecosystems. In addition, there is a need for financial sustainability which involves improving cost recovery rates, and better expenditure management, to address large current funding gaps in the sector. Better budget execution can be achieved by improving absorptive capacity and accelerating project implementation. Additionally, raising utilisation as well as cost recovery rates may require addressing governance effectiveness, political interference, and institutional capacity (Hutton & Varughese, 2016; Joseph et al., 2024).

Servicing Lifecycle Costs to Enable Service Sustainability

While there is need to allocate funds to renovate aging infrastructure, investment in new infrastructure should be based on life cycle costing and stable O&M financing to ensure sustainable and sustained services. This can be achieved through increased transparency, better monitoring, and tracking of both formal and informal service delivery and their outcomes (Garrick et al., 2020; Howard, 2021; Hutton & Chase, 2016).

Improved long-term cost data can shift the focus from funding capital investments to paying more attention to the financial sustainability of system O&M. Benchmarking the direct and indirect costs and benefits of WASH, including public health, social, and environmental impact of different urban and water systems across geographies and technological systems, is essential and can inform planning, investment decisions, and effective resource allocation. Better costing of the full lifecycle costs of urban water and sanitation services can help prioritise funding decisions and focus on equity, safety and sustainability outcomes.

Expanding Funding Decision Criteria for Enhanced Impact

Funding decisions in developing and developed countries should target the sustained delivery of higher and equitable service levels, while accounting for climate resilience investments and factoring principles of the circular economy. Decisions should consider both the monetary and non-monetary values[8] of water and anitation systems that impact socioeconomic development and the environment, contributing to broader goals of sustainability (Howard, 2021; Hutton & Varughese, 2016; UN-Water, 2021; UN-Water, 2023). Climate finance is one such source of development investment that could be better scoped and structured to rehabilitate and safeguard water and sanitation systems, which play a critical role in urban climate resilience and adaptation (GWP, 2014.d.; Van Lieshout, 2023).

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[8] Water and water ecosystems have several economic, environmental and social values. Through its use in the production of food and goods for human consumption, water can deliver direct economic benefits that can be expressed in monetary terms. Water carries other non-eco nomic values, which are difficult to monetise, through its role in spiritual, cultural, religious and emotional aspects (The Valuing Water Initiative, 2020; UN-Water, 2021)

Redirecting Subsidies to Improve Equity

Equitable outcomes can be achieved by more accurately targeting water and sanitation subsidies (Andres et al., 2019). They need to be redistributed between income groups, ensuring they reach the urban poor (Barbier, 2022). Subsidies need to be designed better, made transparent, and supported with complementary policy measures. They should be effectively redirected from centralised systems to other forms of decentralised, formal, and informal systems that are typically more responsive to the needs of the most vulnerable (Barbier, 2022). For example, in Nyeri, Kenya; Kampala, Uganda; and Dakar, Senegal, subsidised water connection charges enabled service coverage to more than double within a decade. In cities like Maputo, Mozambique, and Mzuzu, Malawi, informal supply modes such as standpipes and water kiosks are also subsidised. Some cities have introduced a reduced unit cost of water in the form of a free basic water allowance (South Africa) or Incremental Block Tariffs or Social Tariffs (Bengaluru, Nairobi, Colombo, and Santiago de Cali) (Beard & Mitlin, 2021).

Subsidies can help foster innovations that improve system efficiency. For instance, subsidies could be redirected to innovations that reduce leaks, limit service interruptions, maintain water pressure, or improve safe water reuse. (Barbier, 2022).

6.5 Effecting Sustained Social and Behaviour Change

SBCC interventions, particularly in urban environments, require a combination of strategies/approaches to effectively address multi-level challenges and ensure long-term sustainability (De Buck et al., 2017; Lüthi et al., 2010). For example, water and sanitation messaging to critical stakeholders combined with social marketing techniques can improve awareness on products followed by an increase in willingness to pay and uptake (De Buck et al., 2017). Similarly, while CLTS promotes community-level behavioural change, the lack of broader institutional support can be bridged by integrating the Household-Centred Environmental Sanitation (HCES) approach, which offers a structured, multi-stakeholder institutional framework covering the entire sanitation process from collection to disposal (Lüthi et al., 2010).

To further ensure sustained change, SBCC needs to be part of a broader set of enabling environment, interventions which need to include better institutional mechanisms, financing, capacity building, economic and technological improvements along with improved service provision (Saurí, 2013; UNICEF, 2023; USAID, 2020). Additionally, some key contextual factors identified as key enablers for success include social cohesion, leadership, and diverse involvement (particularly of women at various stages of design, planning, and implementation) (Nelson et al., 2021).

Finally, the recognition of different barriers that influence the implementation of different SBCC approaches can also have an impact on its effectiveness. For example, when considering a community-based approach, the lack of capacity in terms of trained community health promoters/volunteers and efficient institutional actors especially typical to developing countries can be potential barriers in sustenance. In social marketing approaches as well for purchase/construction of toilets, the bureaucratic loan process or high cost of water and sanitation products can be a barrier (De Buck et al., 2017). In a psychosocial approach, ignoring socio-economic categorisation of households can be a barrier to adopt water and sanitation costs for vulnerable households.

7. Conclusion

While deficits in urban water and sanitation systems are acute and complex, addressing them can play a crucial role in mitigating the global water crisis and enhancing sustainability in our cities. Climate change-induced disruptions to the global water cycle are increasingly impacting water availability and quality—resulting in too little, too much, and too dirty water. Change to the GWC have begun to impact the UWC, and hence the urban WASH systems. These changes exacerbate public and environmental health vulnerabilities, as access to clean and reliable water sources becomes more uncertain.

In the face of a growing number of extreme weather events, disasters, and emergencies, urban water and sanitation systems must be designed and adapted to be more resilient, ensuring the safeguarding of human health. There is a need to transition urban water and sanitation systems at scale by shifting from conventional approaches that were path-dependent and ignored non-monetary values of water.
Sustainable water use, considering availability, consumption, and quality, should drive urban planning, development and management decisions. Cities should focus on reviving local sources, reducing consumption, and enhancing efficiency and reuse. Achieving this requires creating enabling conditions through political will, effective leadership, incentives, advocacy, improved capacity and competency of service providers, greater trust between citizens and service providers, better funding decisions and management, and social and behavioural change.

Essentially, transitioning urban water and sanitation systems requires emphasis on all available technological and infrastructure options, along with innovative methods to address entrenched institutional, funding and behavioural barriers. Further research is necessary to clarify outcomes of these measures, identify potential disruptions from other sectors, and determine systematic pathways for transitioning urban water and sanitation systems.

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