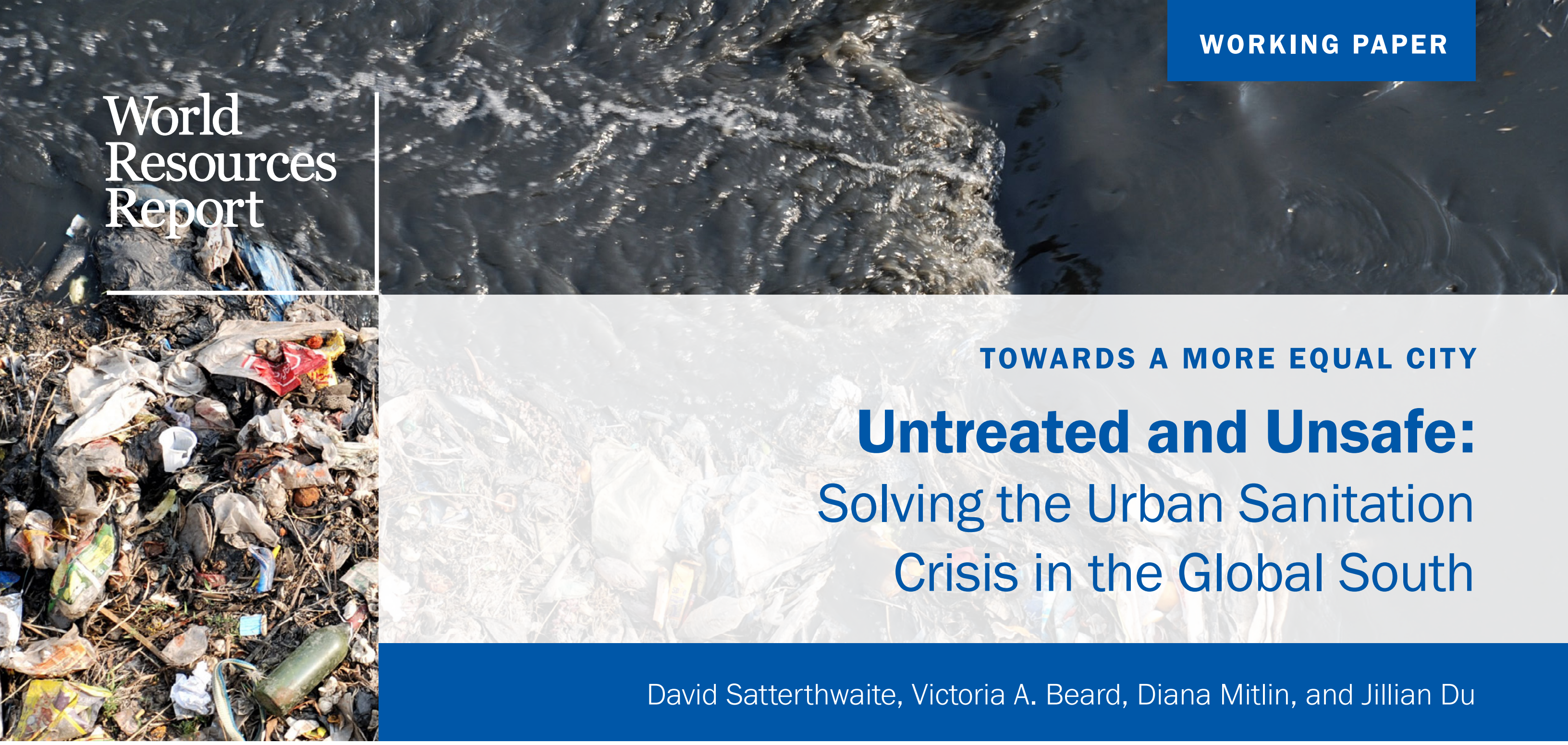

WORKING PAPER

World Resources Report

TOWARDS A MORE EQUAL CITY

Untreated and Unsafe: Solving the Urban Sanitation Crisis in the Global South

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CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form, and their content may be revised.

Suggested Citation: Satterthwaite, D., V.A. Beard, D. Mitlin, and J. Du. 2019. "Untreated and Unsafe: Solving the Urban Sanitation Crisis in the Global South." Working Paper. Washington, DC: World Resources Institute. Available online at www.citiesforall.org.

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EXECUTIVE SUMMARY

Highlights

- Cities must ensure universal access to safe, reliable, and affordable sanitation so that all urban residents can lead productive, healthy, and thriving lives. New analysis of 15 cities in the global South shows that on average, 62 percent of sewage and fecal sludge is unsafely managed somewhere along the sanitation service chain.[1]
- Global monitoring efforts have resulted in an underestimation of the urban sanitation crisis and the risks to public health, the economy, and the environment. New data and analysis at the city and sub-city level is needed to galvanize action.
- Sewers are convenient, safe, sanitary, and work well in dense urban environments and in multistory buildings. From the perspective of the household, sewer connections and services are often less expensive than on-site sanitation options.
- In the absence of universal access to sewers, cities need to find an optimal combination of off-site and on-site sanitation options. On-site sanitation systems place enormous responsibility on households and private providers, and thus require strong government capacity to regulate and enforce sanitation standards to ensure public health and safety.
- Citywide upgrading of informal settlements can improve low-income households' access to urban sanitation. City governments should work with community organizations, nongovernmental organizations, and federations to improve and extend sanitation to informal settlements and address affordability.

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Access to Urban Sanitation Services: What Is at Stake?

Cities must ensure universal access to safe, reliable, and affordable sanitation so that all urban residents can lead productive, healthy, and thriving lives. All people need to defecate and urinate in appropriate spaces and to adequately clean their bodies and wash their hands. Women and girls must be able to attend to their menstrual needs in comfort and with privacy. Cities in high-income countries almost universally respond to these needs. Easily accessible flush toilets are present in homes, workplaces, schools, and public places, and they are connected to sewers and sewage treatment plants. In contrast, access to sanitation facilities and services is more limited and unevenly distributed in cities in the global South.

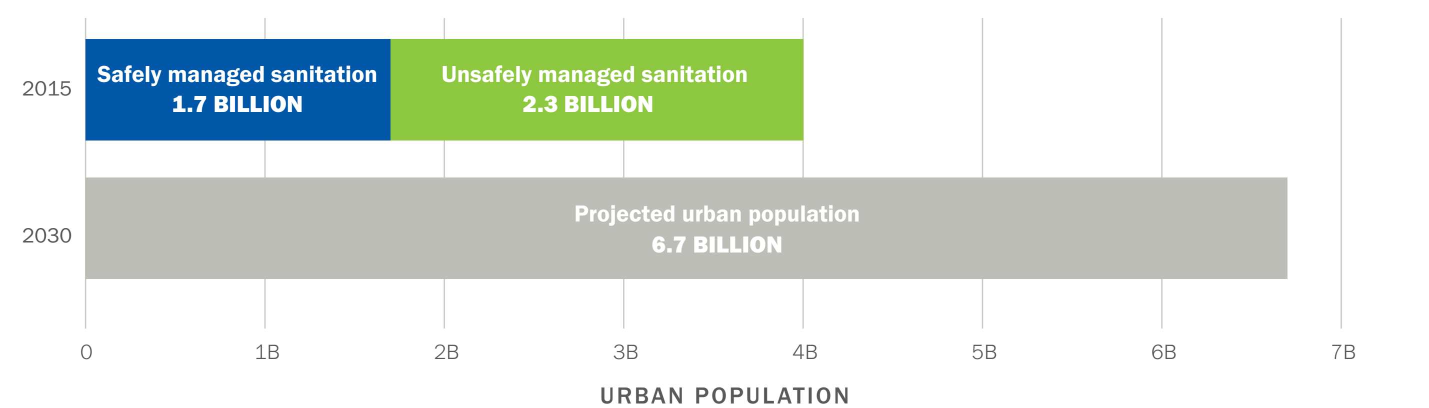
The number of urban residents who lack safely managed sanitation has increased from 1.9 billion in 2000 to 2.3 billion in 2015.[2] In the coming decades, cities in sub-Saharan Africa and South Asia will experience the largest increase in urban population, but these cities have the least financial resources per capita to provide sanitation services.[3] Without action, urban population growth will continue to outpace the capacity of cities and utilities to meet the increased need for sanitation services (see Figure ES-1).

Inadequate access to urban sanitation infrastructure and services negatively affects public health outcomes. In many cities in the global South,[4] most of the population lives in homes without a sewer connection, and untreated or partially treated human waste is released at various points along the sanitation service chain, when human waste is contained, emptied from containers, transported to a treatment plant, and then treated, reused, and disposed.[5] This leads to increased exposure to pathogens both inside and outside homes. The health risks from unsafe sanitation practices include infection and disease, stunting, and the emergence and spread of antimicrobial resistance.[6]

Inadequate urban sanitation also impedes economic growth and productivity and imposes costs on households. It is estimated that globally, unsafe sanitation costs an estimated US$223 billion a year in the form of high health costs and lost productivity and wages.[7] There are four measurable economic benefits associated with access to improved sanitation. First, there is reduced household expenditure on health care.[8] Second, there is the time saved from treating disease.[9] Third, there are savings from reduced premature mortality.[10] Finally, there is the time saved when individuals do not need to locate sanitation facilities or wait to use them.[11] The World Health Organization (WHO) estimates that accessible sanitation saves 30 minutes per person per day.[12] As a result of these benefits, WHO has estimated that over time, every dollar invested in sanitation improvements generates economic returns between US$5.50 and US$9.00.[13]

Inadequate urban sanitation degrades the natural environment, particularly open spaces and water sources. Leaks from piped sewage systems, inadequate on-site sanitation management, poor-quality treatment processes, and open defecation all contaminate urban open spaces, groundwater, and surface water. The disposal of untreated human waste in natural waterways contributes to eutrophication, which threatens endemic plant and animal life.[14] Disposal of untreated

Figure ES–1 | **Meeting sanitation needs will continue to be a challenge given projected urban population growth**



Note: The figure is a global estimate. It can be assumed that the proportion of urban residents without sanitation is higher in the global South.

Sources: WHO and UNICEF, 2017; UN DESA, 2018.

human and household waste in natural waterways also threatens the health of everyone who uses and depends on these water sources, because of exposure to pathogens and other contaminants.[15] Climate change and the resulting increase in urban flooding will exacerbate the negative environmental and health impacts associated with inadequate sanitation.

About This Paper

The World Resources Report (WRR), *Towards a More Equal City*, views sustainable cities as equitable, economically productive, and environmentally sustainable.[16] Through a series of research papers, the WRR addresses this overarching question: Can providing equitable access to high-quality core services improve the economy and environment of the city as a whole? Contributing to this body of work, this paper examines the challenge of providing equitable access to sanitation in cities in the global South, the magnitude of the current urban sanitation crisis, and the global underestimation of this crisis. While acknowledging the importance of local context and the diverse mix of sanitation solutions required in the short and medium term, the paper evaluates the advantages and disadvantages of different actionable approaches to safely manage human waste. It suggests priority action areas for cities to move towards equitable access to sanitation services.

The Underestimation of the Urban Sanitation Crisis

Comparative analysis of global sanitation data has led to an underestimation of the risk to urban populations. *Improved sanitation* is a category used by the WHO and UNICEF's Joint Monitoring Programme (JMP) to compare service levels across countries. This category includes such diverse sanitation practices and conditions that it ceases to be meaningful for understanding public health risks in high-density urban areas. Some urban sanitation practices, such as the use of self-provisioned drains that remove untreated human waste from the household or plot but dispose of untreated waste in nearby waterways, are mistakenly identified as improved sanitation. The JMP sanitation categories also pay inadequate attention to who is responsible for which parts of the sanitation service chain, and it does not adequately consider affordability from the perspective of low-income households. In addition, the dearth of reliable city and sub-city level data about urban sanitation practices and access to infrastructure and services inhibits meaningful action.

Sanitation Conditions and Practices in 15 Cities in the Global South

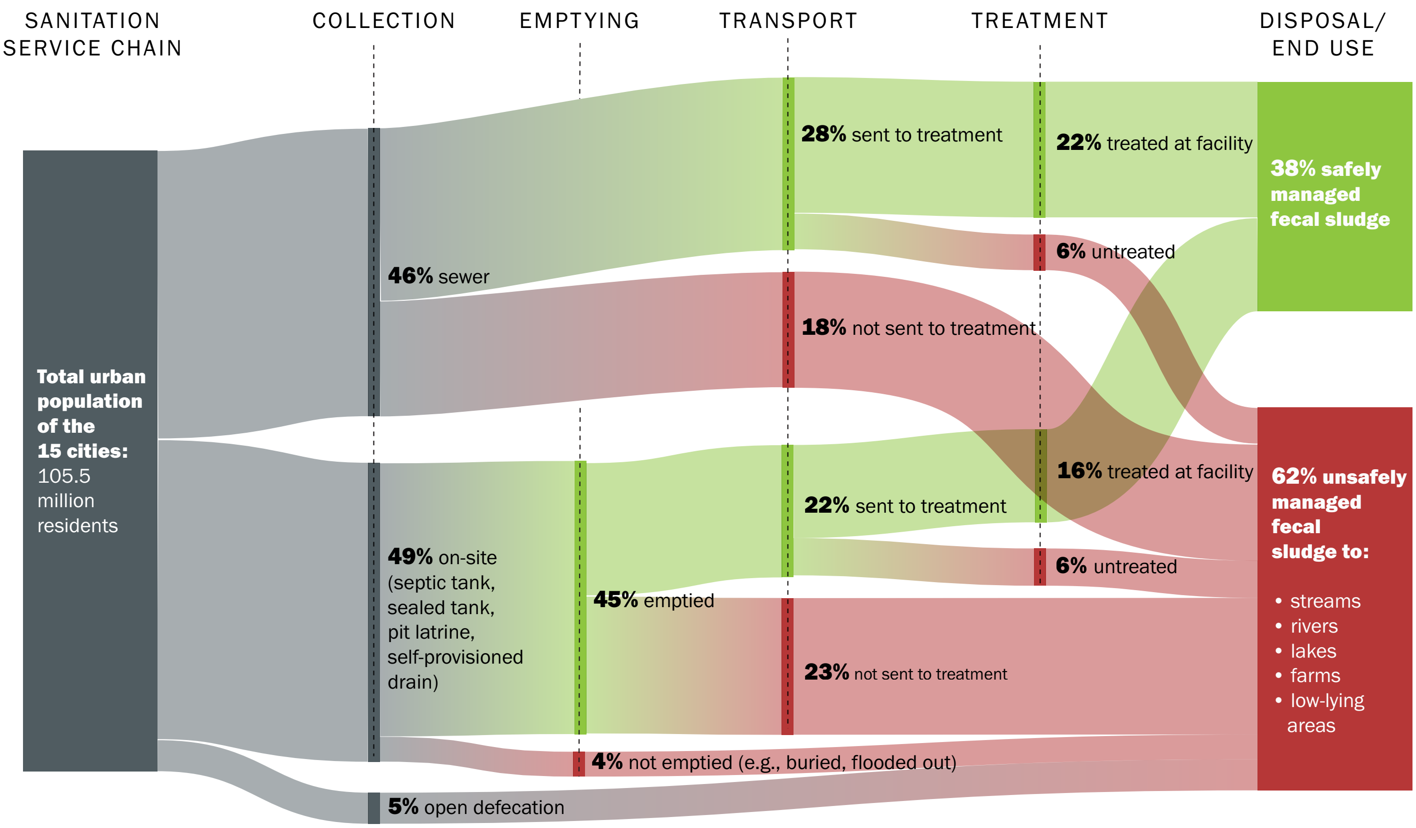
Based on new analysis of 15 cities, on average 62 percent of sewage and fecal sludge is unsafely managed (see Figure ES-2). The 15 cities analyzed include Kampala, Uganda; Lagos, Nigeria; Maputo, Mozambique; Mzuzu, Malawi; Nairobi, Kenya; Bengaluru, India; Colombo, Sri Lanka; Dhaka, Bangladesh; Karachi, Pakistan; Mumbai, India; Caracas, Venezuela; Cochabamba, Bolivia; Rio de Janeiro, Brazil; São Paulo, Brazil; and Santiago de Cali, Colombia. In Santiago de Cali, the city that provides the highest rate of sanitation service, 87 percent of human waste is safely managed. In comparison, in three cities, Caracas, Colombo, and Karachi, none of the human waste is safely managed. In many cities, intermittent water supply prevents sewers from working properly.[17] Overall, household sewer connections were significantly less common in cities in South Asia and sub-Saharan Africa.

In many of the 15 cities, households use self-provisioned drains to dump untreated human waste and household wastewater into storm drains and nearby waterways. Researchers in 9 of the 15 cities—Bengaluru, Caracas, Cochabamba, Colombo, Kampala, Karachi, Lagos, Nairobi, and Santiago de Cali—all acknowledge the widespread use of self-provisioned drains. Despite this, there are no official figures on the prevalence of such drains at the city level.

In some cities, household costs for sewer connections were on par or less expensive than building a private septic tank. Although sewers represent a significant investment on the part of cities, sewers eliminate the need for households to pay to empty a septic tank and to transport and treat fecal sludge, although households may incur a monthly sanitation fee for service. In all cities, the costs associated with on-site sanitation systems or connecting to sewers (where they exist) are high for low-income groups in proportion to monthly household income.

Pit latrines are unsuitable in densely populated urban environments or multistory residences. Pit latrines are the least expensive sanitation option for households to construct, but they are at risk of leaking and have additional costs associated with emptying, transportation, and treatment. Many cities do not have the capacity to safely manage fecal sludge. Based on our study, 10 out of 15 cities had fecal sludge management regulations, and 9 reported that these were enforced. Five cities did not regulate fecal sludge.

Figure ES–2 | **In 15 global South cities, 62 percent of fecal sludge is unsafely managed**



Note: The percentages are weighted by population.

Source: Authors' analysis, based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

The provision of sanitation infrastructure from the perspective of the household has inflexible, high, one-time costs. In informal settlements, the most common forms of on-site sanitation (pit latrines and private septic tanks) range in construction cost from 128 to 759 percent of average household monthly incomes. This is a significant financial burden on low-income households. Many households rent and are therefore unable to either provide their own sewer connections or construct private sanitation facilities. See Figure ES–3 for a summary of the sanitation access data of the 15 cities.

The Challenge of Affordable Urban Sanitation

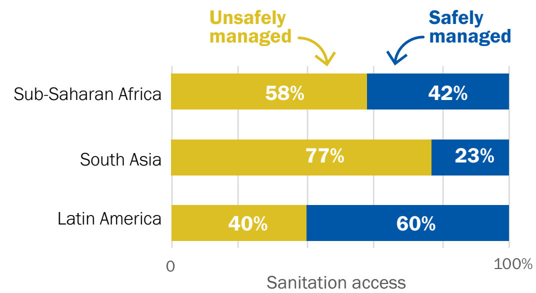
Too little attention has been paid to the affordability of sanitation services for households. Septic tanks and pit latrines vary in their up-front costs, maintenance costs, and life cycle costs. In addition, cost data is often lacking for different stages of the sanitation service chain. More specifically, the cost to empty containers, and transport, treat, and dispose of fecal sludge often varies greatly or is unknown. This makes it difficult to compare options and generalize about sanitation costs.

An alternative approach is to consider what low-income households can afford to pay. Research suggests that low-income households in urban sub-Saharan Africa can only afford to pay between $3 and $4 a month for sanitation.[18] They may be unable to pay higher rent for a room with sanitation facilities, and they may lack access to pay toilets. Communal or public toilets can dramatically lower the capital cost per household served—from around $300–$450 (as is common in sub-Saharan Africa for a good-quality individual toilet) to $22 per household.[19] If land is available, communal toilet blocks are easier to install than individual household solutions.

It is in the public interest for cities to ensure that sanitation facilities are affordable for low-income groups. The public health costs of unsafe sanitation are difficult to disentangle and trace in densely populated urban areas. Households do not always have a complete picture of what happens to the waste

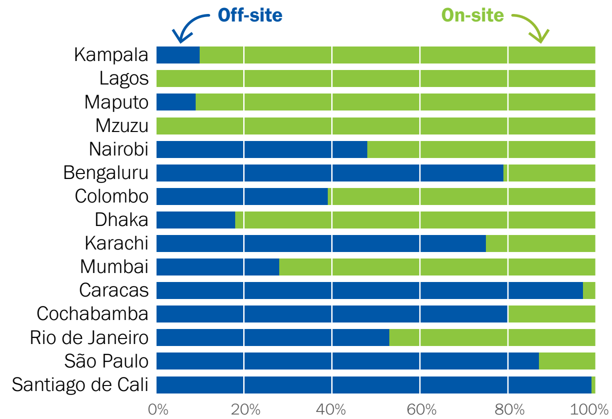
Figure ES–3 | **New analysis of sanitation access in 15 cities in the global South**

1. Safely managed sanitation varies by geographic region. On average, 62% of sewage and fecal sludge is unsafely managed in 15 cities in the global South.

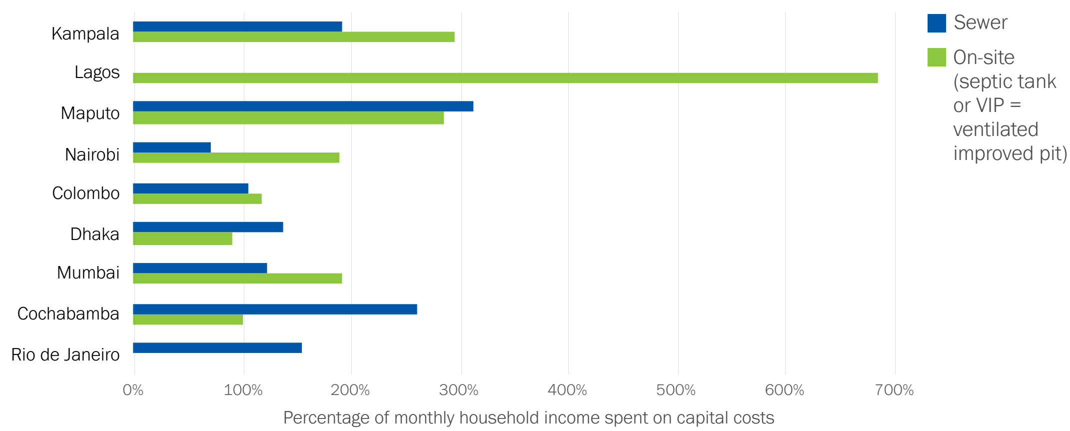


Note: Figures are weighted by population.

2. In many cities a combination of off-site and on-site sanitation approaches are used. Safely managed on-site sanitation is a challenge in densely populated urban areas. For example in Dhaka, the most densely populated city in our sample, 75% of households rely on on-site sanitation.



3. The household capital expenditure required for sanitation is high for off-site and on-site solutions. When sanitation costs are unaffordable, households resort to less expensive and unsafe approaches to sanitation.



Source: WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

downstream or when containment is subterranean. To ensure we address the sanitation needs of low-income households, we consider initiatives that are not principally regarded as sanitation initiatives but rather as informal settlement upgrading that includes sanitation components. Such initiatives underscore the importance of local participation and the need for state and nonstate actors to work together to achieve universal access to sanitation services.

Recommendations

We identify action areas and enablers to ensure equitable access to safe, reliable, and affordable sanitation (see Figure ES–4). Below are four high-priority action areas for cities and utilities, city leaders, policymakers, urban planners, government officials, and civil society actors concerned with sanitation access.

- ***Cities need to extend the sewer network to household, communal, and public toilets.*** Sewers and simplified sewers are convenient, safe, and sanitary and work well in densely populated urban environments and where multistory buildings are common. Sewers reduce the responsibility for and cost of sanitation services from the perspectives of individuals and households. However, building, maintaining, and extending sewer systems requires large capital investments and daily supplies of water to work properly.

- ***In the absence of sewer systems, cities need to support and regulate on-site sanitation options such as septic tanks and pit latrines.*** Presently, quality and safely managed on-site sanitation is unaffordable for many low-income households, so unsafe practices persist. Cities need to work with households and communities to make the entire on-site sanitation service chain safe, reliable, and affordable. On-site sanitation also requires strong public capacity to regulate and enforce safe practices.

- ***Cities should take a citywide approach to upgrading informal settlements that addresses the need for urban sanitation services.*** Cities need to work with community organizations, NGOs, and federations to improve and extend sanitation services to low-income groups.[20] Cities should collaborate with these organizations to address access to sanitation because they are in a position to respond to users' needs and priorities while working within local constraints, particularly affordability.

- ***Cities need to make a variety of sanitation services more affordable for low-income households.*** This includes subsidizing the capital costs of sanitation from the perspective of the household (i.e., bathroom construction, the cost of toilets, and septic tank construction). It also includes building communal toilet blocks and public toilets. Making sanitation affordable means subsidizing the cost of a sewer connection to household, communal, and public toilets, as well as subsidizing the costs of safe on-site sanitation management, including emptying, transporting, treatment, reuse, and disposal.

Cities and sanitation authorities should establish data collection systems that provide disaggregated sanitation information to galvanize and inform action. City and sub-city level data about who is responsible for the sanitation service chain and the affordability of different services are needed to support urban sanitation policy and action. City and national governments should support the collection of more detailed sanitation data from censuses and household surveys. They should also support the use of relevant health data from local vital registries and hospital and health care records regarding death and illness. Community-led data collection and mapping can provide highly reliable information about local conditions, including access to sanitation services, the cost of sanitation, availability and use of sanitation infrastructure, and local sanitation practices.

Cities need to enhance their capacity to finance, regulate, and enforce access to off-site and on-site sanitation systems. Constructing and extending sewers requires large-scale investment finance. National governments and international agencies have not invested enough in sanitation to enable cities in the global South to keep pace with urban population growth. In the absence of these investments, the financial burden for sanitation falls on the city and the utility. On-site solutions require less capital investment on the part of the public sector. However, on-site sanitation systems place enormous responsibility on households and private providers to ensure public health and safety. Cities need to regulate and enforce on-site sanitation safety measures, yet many have weak or nonexistent regulatory capacity. Subsidies are needed to ensure sanitation access to low-income households. If households do not have access to affordable sanitation services, they will not manage their waste safely.

Conclusion

The need for sanitation is shared by everyone, yet ways to meet this need depend on the local context. Global monitoring efforts have led to a gross underestimation of the urban sanitation crisis. To solve it, cities and utilities should focus on extending the sewer network to households and communal and public toilets. While sewers are convenient, safe, and sanitary, they require a large initial capital investment on the part of the public sector and a daily sufficient supply of water.

Most cities in the global South will require a combination of off-site and on-site solutions to meet the sanitation needs of their growing populations. Where sewer systems are not available, access to safe and affordable on-site sanitation must be provided, supported, and regulated. Given the high costs of on-site sanitation solutions to households and the inherent public health risks, these solutions should be viewed as short- and medium-term approaches to providing access to sanitation in dense urban settings. During this period of transition, cities need to lay the foundation for off-site solutions like sewers to work. These include upgrading and legalizing informal settlements, as well as prioritizing efforts to improve water and sanitation services in these areas.

Finally, cities and utilities need to make access to all aspects of off-site and on-site sanitation more affordable. Where safely managed sanitation is not affordable, households will continue to use unsafe practices, which puts everyone's health at risk. Achieving access to adequate and equitable sanitation for all and ending open defecation, as stated in the Sustainable Development Goals (SDG), will require commitment to investing significant financial resources as well as building public sector capacity to regulate the performance of the entire sanitation service chain.

Figure ES-4 | **Priority action areas for cities and urban change agents to improve equitable sanitation access**

ACTION AREA 1:
Extend the sewer and simplified sewer networks to household, communal, and public toilets

- Sewers and simplified sewers are convenient, safe, and sanitary
- Sewers work well in densely populated urban areas and where residents live in multistoried buildings
- Sewers reduce household responsibility and costs for sanitation

ACTION AREA 2:
In the absence of sewer systems, support and regulate on-site sanitation

- Shift the cost, responsibility, and associated risk for on-site sanitation systems away from households and private providers to the public sector
- Build capacity to regulate and enforce safe fecal sludge management at every step along the sanitation service chain

ACTION AREA 3:
Take a citywide approach to upgrading informal settlements and include access to sanitation services

- Upgrading informal settlements should address sanitation needs
- Coordinate between citywide sanitation initiatives and locally determined sanitation practices
- Cities, community organizations, NGOs, and federations should work together to improve sanitation access, particularly for low-income households

ACTION AREA 4:
Make sanitation services affordable for low-income households

- Subsidize household capital costs of sanitation facilities and provide affordable communal toilet blocks and public toilets
- Subsidize the cost of household sewer connections and connections to communal and public toilets
- Subsidize the costs of safe on-site sanitation management
- Ensure water is affordable for households

ENABLERS

DATA
Improve city and sub-city level information on sanitation practices and access to infrastructure and services

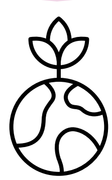
FINANCE
Increase capital investment in sanitation infrastructure and maintenance

GOVERNANCE
Increase regulatory and enforcement capacity to encourage safe fecal sludge management

EQUITABLE ACCESS TO SAFE, RELIABLE, AND AFFORDABLE SANITATION

BENEFITS

IMPROVED HEALTH AND WELL-BEING
Reduction in diseases resulting from exposure to contaminated water and food and through direct human contact



ENVIRONMENTAL SUSTAINABILITY
Reduced contamination of natural water bodies and reduced risk of eutrophication

ECONOMIC PRODUCTIVITY
Improved health and time saved

Note: NGOs refers to "nongovernmental organizations."

Source: Authors' analysis.

Glossary

Black water	Wastewater from sanitation facilities that is a mixture of urine, feces, menstrual waste, flush water, anal cleansing water, and dry cleansing materials.
Colocated plants	A wastewater treatment facility and a fecal sludge treatment facility located close together to facilitate the treatment of sewage and fecal sludge efficiently.
Composting toilet	A dry toilet in which excreta are collected with cleansing material in a composting chamber and carbon-rich materials are added to produce inoffensive compost.
Decentralized wastewater treatment system	A small-scale system that collects, treats, discharges, and sometimes reclaims wastewater from a small community or service area.
Desludging	The process of removing the accumulated sludge from a septic tank, pit latrine, or treatment facility.
Ecological sanitation	An approach that aims to safely recycle nutrients, water, and energy contained in wastewater in a way that minimizes the use of nonrenewable resources.
Fecal sludge	Biosolids that come from on-site sanitation technologies or systems and have not been transported through a sewer.
Fecal sludge management	Includes the containment, collection, emptying, transport, treatment, and safe end use or disposal of human waste and black water from on-site technologies.
Fecal sludge treatment plant (FSTP)	Infrastructure designed to convert and treat fecal sludge into a product that is safe for end use, whether it is used or not.
Flying toilet	When fecal sludge is captured in a plastic bag or other material and thrown into an open space.
Gray water	Water generated from washing food, clothes, and dishware as well as from bathing, but does not include human waste or toilet waste.
Gulper	A hand pump specially designed for emptying fecal sludge from pit latrines, septic tanks, and other on-site sanitation when paths are too narrow for alternative conventional pumps.
Hanging toilet	A sanitation facility built directly over a water body, where untreated human excreta are directly disposed of in the water.
Off-site sanitation	A system in which excreta and related wastewater are collected and conveyed away from the plot where they are generated.
On-site sanitation	A system in which excreta and wastewater are collected, stored, and sometimes treated or partially treated on the plot where they are generated.
Open defecation	The practice of defecating outside and not in a designated toilet or sanitation facility.
Pit latrine	A pit that captures human waste and usually includes a slab and superstructure and can function with water or without water.
Primary sewage treatment	The first major stage in wastewater treatment that removes solids and organic matter using gravity for sedimentation or flotation.
Public sewer connectivity	The proportion of households connected to municipal sewage service compared to those households offered service within a given area.
Sanitation service chain	This includes all the steps required for safe disposal of human waste, including collection, conveyance, treatment, reuse, and disposal.
Secondary sewage treatment	This follows the primary sewage treatment to achieve the removal of biodegradable organic matter and suspended solids from wastewater effluent.
Self-provisioned drain	A drain built by a household or community to convey untreated human waste, black water, and sometimes gray water away from the plot.
Septage	A historical term here to describe excrement and other waste material contained in or removed from a septic tank.

Glossary (continued)

Septic tank	A watertight chamber through which black water and gray water flow for primary treatment.
Sewage	A subset of wastewater, including black water and gray water, that is transported through a sewer system.
Sewer	Typically, a subterranean system of closed pipes that conveys black water and gray water ideally to a wastewater treatment plant.
Simplified sewer	A network or a line of sewers that is constructed using smaller pipes, at a shallower depth, and sometimes at a flatter gradient than conventional sewers.
Soak pit	A covered, porous-walled, underground chamber that allows wastewater to slowly soak into the ground.
Tertiary sewage treatment	This follows the secondary sewage treatment to achieve enhanced removal of residual suspended solids and other pollutants from effluent.
Urine-diverting dry toilet	A toilet that operates without water and has two chambers to separate urine from feces.
Vacutug	Pumps out fecal sludge and consists of a half-cubic meter (m^3) steel vacuum tank connected to a vacuum pump, which is run by a gasoline engine.
Vacuum truck	A truck equipped with a pump, a hose, and a storage tank used for emptying fecal sludge from septic tanks or pits.
Ventilated improved pit (VIP) latrine	A pit that allows for continuous airflow through the ventilation pipe to reduce odors and acts as a trap for flies.
Wastewater	May include black water, gray water, and storm water depending on whether storm water is combined or separated from sewage.
Wastewater treatment plant	Infrastructure designed to treat wastewater so it is safe for disposal and, depending on the level of treatment, reuse.

Source: The glossary builds on definitions provided by the International Water Association, SFD Promotion Initiative, and Joint Monitoring Programme (WHO and UNICEF). For more information, see SuSanA (2018c) and Tilley et al. (2014).

Abbreviations

ACCA	Asian Coalition for Community Action
CBS	container-based sanitation
DHS	Demographic and Health Survey
FSTP	fecal sludge treatment plant
GDP	gross domestic product
JMP	Joint Monitoring Programme
KCCA	Kampala Capital City Authority
MAPET	manual pit emptying technology
NGO	nongovernmental organization
O&M	operations and maintenance
OPP	Orangi Pilot Project
RTI	Research and Training Institute
SDG	Sustainable Development Goal
SDI	Slum/Shack Dwellers International
SFD	shit flow diagram
SOIL	Sustainable Organic Integrated Livelihoods
UBSUP	Upscaling Basic Sanitation for the Urban Poor Programme
VIP	ventilated improved pit
WHO	World Health Organization
WRI	World Resources Institute
WWTP	wastewater treatment plant

1. FRAMING URBAN SANITATION IN THE GLOBAL SOUTH

Every human being—regardless of sex, age, nationality, educational attainment, and income level—needs access to safe, reliable, and affordable sanitation facilities at home and in public. These needs are universal, and meeting them is a precondition for human dignity, health, economic productivity, and environmental sustainability. All people need to be able to defecate and urinate in appropriate spaces as well as wash their hands. Women and girls must be able to attend to their menstrual needs in comfort and with privacy. These basic needs mean that human waste must be safely contained, transported, treated, reused, and disposed of.

In many cities of the global South, the challenge of providing universal access to quality urban sanitation is further complicated by high population densities; water scarcity and climate change; low household incomes and the wide range of city capacities for planning, governance, and finance; and the inherent cultural sensitivities around the management of human waste.[21] This paper proposes a menu of actionable approaches for cities in the global South to meet the demand for universal access to sanitation services. This effort is in line with Sustainable Development Goal (SDG) 6, which seeks to "ensure availability and sustainable management of water and sanitation for all," and SDG target 6.2, which aspires to "achieve access to adequate and equitable sanitation and hygiene for all and end open defecation by 2030."[22]

In most cities in the global South, improved sanitation, infrastructure, and services have not kept pace with population growth.[23] Between 2001 and 2030, approximately 600 million residents will be added to urban populations that lack access to sanitation.[24] For example, between 1990 and 2015, improved urban sanitation coverage increased from 37 to 47 percent in the world's lowest-income countries, but despite improvements at the national level, the percentage with access in urban sub-Saharan Africa did not change during this period.[25]

The World Health Organization (WHO) 2018 guidelines underscore the link between access to safe sanitation and improvements in health and well-being.[26] In 2010 it was estimated that 280,443 diarrheal deaths in low- and middle-income countries were attributed to contact with infected soil and inadequate sanitation, along with an estimated 5 million disability-adjusted life years lost globally.[27] The health risks from unsafe sanitation practices are numerous and varied, and include infection and disease, stunting, and the emergence and spread of antimicrobial resistance.[28] Improved urban sanitation in low- and middle-income countries is also linked with higher socioeconomic status.[29]

Sanitation interventions have limited positive impacts on health if they fail to consider the potential for exposure along the entire sanitation chain, the range of pathogens, and the diverse transmission pathways to which urban populations are exposed.[30] In many cities, untreated or partially treated human waste is at risk of "leaking" at various points along the sanitation service chain: when waste is emptied from containers, transported to a treatment plant, during treatment, at the time of reuse, and when it is disposed of.[31] Some work in this area suggests pathogen flows and their public health risks are more effectively addressed by achieving a safe threshold of community sanitation coverage.[32]

It is estimated that unsafe sanitation costs approximately US$223 billion a year globally in the form of high health costs and lost productivity and wages.[33] At the national level, health problems, absenteeism, and lost time associated with a lack of access to improved sanitation are estimated to significantly impede economic growth and productivity.[34] In 2007 the World Bank's Water and Sanitation Program launched the Economics of Sanitation Initiative to measure the economic cost of poor sanitation and hygiene. This effort found that in 2012, poor sanitation and hygiene cost Kenya $324 million.[35] A subsequent study of 18 African countries estimated that between 1 and 2.5 percent of gross domestic product (GDP) is lost due to poor sanitation.[36] Elsewhere across the global South, national economic losses related to poor sanitation are even higher: 6.3 percent in Pakistan, 6.4 percent in India, and 7.2 percent in Cambodia.[37] Although these estimates are based on a series of assumptions that are difficult to verify, they do underscore that there is an economic cost associated with inadequate sanitation.

Economically, at the household level there are four measurable benefits associated with access to improved sanitation. The first is reduced household expenditure on health care, such as the cost of treating diarrheal disease, respiratory infections, and chronic undernutrition. The second benefit is the time saved from treating disease, including avoiding lost productivity as well as time spent caring for a sick family member.[38] The third economic benefit involves savings related to reduced premature mortality,[39] and the fourth is time saved when sanitation facilities are more accessible, including not having to wait for public toilets or to find a spot to defecate.[40] The World Health Organization (WHO) estimates that accessible sanitation saves 30 minutes per person per day.[41] As a result of these benefits, WHO has estimated that over time, every dollar invested in sanitation improvements generates returns between $5.50 and $9.00.[42]

Among the most significant environmental risks associated with inadequate sanitation is the contamination of water sources. Leaks from underground sewers, ineffective septic tanks, and poorly constructed pit latrines can contaminate groundwater. Flooded pit latrines, open sewers, and open defecation all have the potential to contaminate surface water, which is strongly associated with the propagation of filariasis, a parasitic disease.[43] There is also an important link between the release of untreated human waste into rivers, streams, and lakes and the rise of eutrophication, which is where natural water bodies become overly rich in plant biomass due to higher levels of nitrogen and phosphorus.[44] Eutrophication is responsible for numerous negative outcomes, including water hyacinth blooms, the eradication of endemic fish species, and the rapid growth of phytoplankton blooms.[45] In extreme cases this can result in monospecies blooms, like cyanobacteria, which adversely affects the health of humans and animals.[46]

There are three main aspects to urban sanitation: reliability, safety, and affordability. This paper examines all three at the city level, to varying degrees of depth. Building on the World Resources Report (WRR) framework *Towards a More Equal City*,[47] Section 1 describes how urban sanitation affects health and well-being, the economy, and the environment. Section 2 describes the unique challenge of sanitation in densely populated urban environments, explains the difference between off-site and on-site approaches to sanitation, and underscores the importance of considering the entire sanitation service chain. Section 3 highlights how global sanitation definitions have led to an underestimation of the scale and scope of the urban sanitation crisis. Section 4 analyzes new data on sanitation conditions, practices, and services in 15 cities in the global South. Section 5 discusses the challenge of affordable sanitation services from the household and city perspectives. Section 6 focuses on priority actions for cities and the advantages and disadvantages of on-site and off-site sanitation approaches, drawing on examples from their use in cities in the global South. Section 7 focuses on enabling conditions for cities, specifically the governance and regulatory capacity and adequate financial flows to meet capital investment and system maintenance expenditures. Section 8 emphasizes the importance of local contextual elements, as well as time, as cities search for the optimal combination of sanitation services in the short, medium, and long term to solve the urban sanitation crisis.

2. THE SANITATION CHALLENGE IN DENSELY POPULATED URBAN AREAS

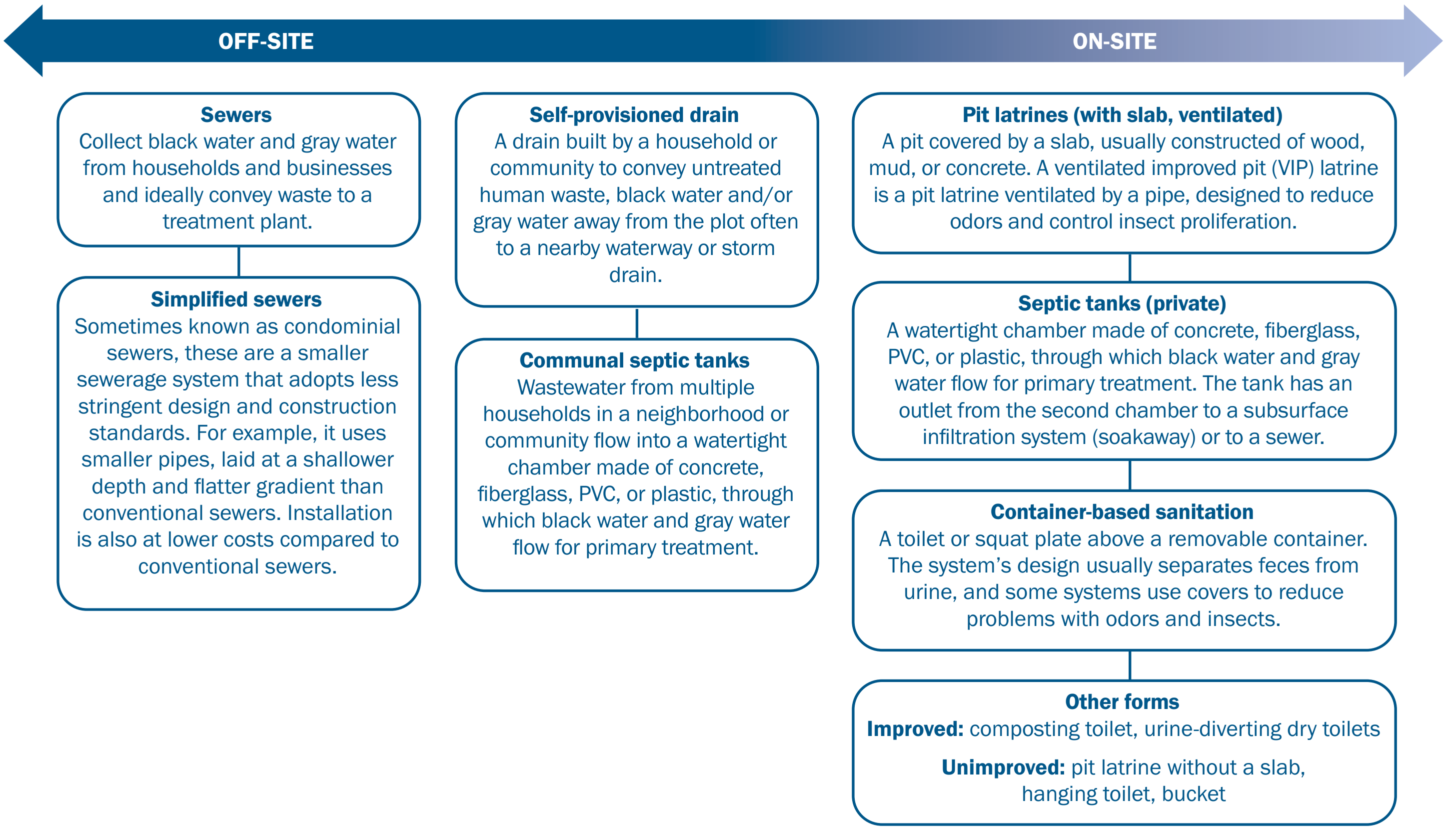
Improving urban sanitation services depends on a host of contextual factors that differ from city to city and often neighborhood to neighborhood. Among these are population density; physical conditions such as geology, topography, and the availability of water; differences in individual or household capacities to pay for services; cultural norms, practices, and expectations; and enabling and inhibiting factors at the city level, such as the capacity for planning, governance, and finance, as well as various technological capacities. In many cities, access to sanitation in informal settlements is further complicated by regulations that prohibit services due to residents' illegal status. However, the importance of local context rarely factors into policy discussions, which leads to an underestimation of the challenges of meeting urban sanitation service needs.

Urban sanitation is usually understood in terms of off-site and on-site approaches, but there are areas of overlap. *Off-site sanitation* is when human waste and associated black water is removed from a plot, usually through waterborne sewer technology.[48] In this system, human waste is ideally conveyed to a plant for treatment, some portion of the waste is reused, and the remainder is safely disposed of. There are different types of sewer systems. Some systems separate human and household wastewater from storm water and runoff, and other systems combine these.

On-site sanitation describes a system in which human waste and associated black water are collected, stored, and sometimes treated on the plot where they are generated or are eventually transported to a plant for treatment, reuse, and disposal. Examples of on-site sanitation include septic tanks, pit latrines, and other types of containers.[49] Other urban sanitation options lie somewhere between off-site and on-site, such as communal septic tanks and self-provisioned drains. Figure 1 provides examples of the urban sanitation continuum.

The task of providing sanitation services in cities is made more challenging by the prevalence of small plot sizes, land scarcity, and multistory dwellings. Low-income urban households usually have limited indoor and outdoor space. In many struggling and emerging cities, urban residents rent small one- or two-room dwellings with inadequate or no sanitation facilities.[50] High-density urban contexts that feature multistory housing units require different sanitation solutions.[51] Sanitation solutions that work well in low- and lower-density rural areas do not work well in high-density urban ones.

Figure 1 | **The range of sanitation approaches used in cities in the global South**



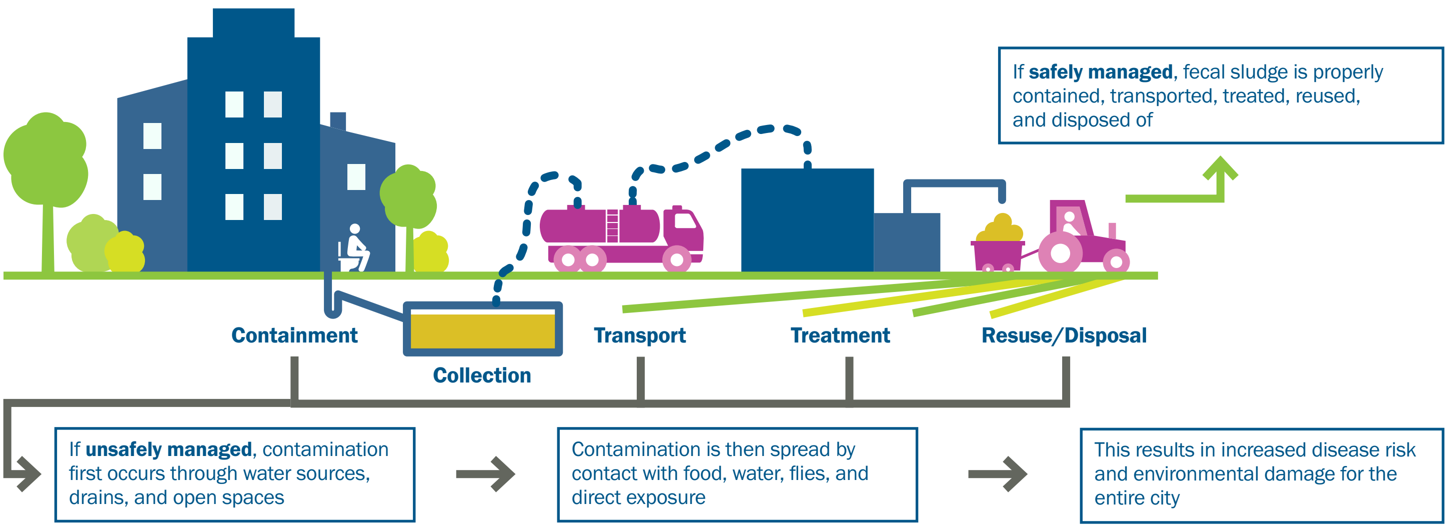
Source: Based on authors' analysis.

Sanitation-related contamination and health risks are also much more significant in high-density urban areas. Cities must consider the entire sanitation service chain, including containing, emptying, transporting, treating, reusing, and disposing of waste.[52] In higher-density areas, the service chain becomes increasingly complex due to the limited feasibility of on-site options, and the health risks associated with improperly managed human waste.[53] In struggling and emerging cities in the global South, a mix of different systems, technologies, and methods are used at each stage of the service chain and often operate simultaneously.[54] This complexity, along with variations in planning, governance, financing, and affordability, results in potential "leakage points" where untreated human waste can be released into the environment (see Figure 2).[55]

In on-site sanitation, the first link in the chain is containment. These systems are often designed and constructed by households, and leakage can result from improper construction and maintenance. The second link is the process of removing fecal sludge from the container. On-site sanitation systems are emptied either manually or mechanically. Without strong regulation and enforcement, households that cannot afford emptying services may allow their containers to "flood out" during the rainy season, or hire informal or private emptiers who may not follow proper safety and treatment procedures. The third link is transporting fecal sludge to a treatment facility. There are challenges to giving trucks access to on-site containment systems in densely populated irregular settlements. The fourth link in the chain is treatment, and capacity varies widely from city to city. The final links are reuse and disposal.

The sanitation service chain illustrates the complexity of providing equitable access to safe, reliable, and affordable sanitation services in cities. Practitioners and researchers have recently developed so-called "shit flow diagrams" (SFDs) for more than 60 cities to provide snapshots of the sanitation service chain for each city.[56] Based on a literature review, key informant interviews, and focus group discussions, the enumerator collects data at each point of a city's sanitation service chain. The goal of the SFD is to highlight the main points of failure in a city's sanitation system. It also indicates whether the bulk of

Figure 2 | **The sanitation service chain and potential leakages**



Note: This is an example of on-site sanitation, which is the predominant method for cities in the global South.

Source: Authors' analysis, based on WHO, 2018.

Box 1 | Cities Need to Prioritize Sanitation Outside the Home

Providing sanitation facilities in a home does not in and of itself solve the problem of open defecation. Cities must also provide facilities outside the home in schools, hospitals, workplaces, bus and train stations, and other public spaces to protect urban populations from disease, infection, and other health risks. In schools, sanitation services must be suitable for both girls and boys. Where girls lack access to sanitation facilities in school, they experience increased absenteeism or drop out when they start to menstruate. Schools may need to open early to allow students who lack such facilities at home to use them before classes start. Sanitation is also needed in a variety of workplaces, including informal ones. Because of the high proportion of people who work in the informal economy—which in some struggling and emerging cities is as much as 80 percent—access to public sanitation facilities for waste pickers, street vendors, market traders, transit providers, and construction workers should be prioritized. In general, the provision of urban sanitation services outside the home is under-researched, and there is a need for urban policy to better address this issue.

Note: For more information on choice, quality, and access to health facilities beyond the household level, see the family planning indicators of Johns Hopkins's Performance Monitoring and Accountability 2020, https://www.pma2020.org/indicators-topic-area.

Sources: Nallari, 2015; Chen and Beard, 2018; Estrin, 2018.

the contamination is occurring near households, if it is spread throughout the surface drainage network, and whether it affects downstream discharges into water bodies.

Most SFDs show the paucity of safe fecal sludge treatment and disposal practices. Although SFDs reveal a city's lack of fecal sludge management services, they do not represent the diverse spatial conditions and practices used across a city to manage human waste, especially conditions in informal settlements.[57] If city planning is to improve access to sanitation services, a more detailed spatial assessment of the sanitation situation is needed. SFDs provide a useful starting point for understanding sanitation service deficiencies and a city's potential for contamination.[58] Box 1 highlights the often-overlooked challenge of providing access to sanitation services outside the home.

3. THE UNDERESTIMATION OF THE URBAN SANITATION CRISIS

In 2015 the United Nations introduced SDG targets 6.1 and 6.2, which focus on access to safely managed water and sanitation facilities. WHO and the United Nations Children's Fund, through the Joint Monitoring Programme (JMP), are mandated to monitor global progress on SDG 6. The JMP's work is indispensable for raising international awareness and focusing attention on the need to provide equitable access to water and sanitation services. These data are used for advocacy, policy, and to inform global action,[59] and they are the only statistics that reflect global coverage, so any assessment of sanitation access globally must engage with these categories. Despite the usefulness of the JMP's global comparisons, they have contributed to the underestimation of the urban sanitation crisis.

The JMP service ladder categorizes sanitation into two broad categories: improved or unimproved. Improved facilities are further subdivided between those that are shared between two or more households and those that are not shared. The top of the sanitation service ladder is safely managed, followed by basic, limited, unimproved, and open defecation (see Table 1).

These categories are limited in their ability to inform urban sanitation policy and action. As discussed earlier, urban areas have unique characteristics, such as dense, informal settlements, which complicate the safe use of on-site sanitation practices. Furthermore, the "safely managed" category includes pit latrines and septic tanks—sanitation practices that are extremely difficult to regulate and safely manage in urban settings that are marked by high poverty rates, informal construction, increased flooding risks, and limited municipal capacity for regulation, treatment, reuse, and disposal. Finally, these categories pay inadequate attention to the affordability of different sanitation options.

At the national level there are often discrepancies in sanitation statistics depending on which definition is used. For instance, in 2013 in Nigeria—which has Africa's largest urban population—only 6 percent of urban households had their own toilet (not shared with other households) connected to a sewer;[60] but by 2015, 39 percent had improved basic provision after criteria were broadened to include many other toilet forms, such as pit latrines with slabs, composting toilets, ventilated improved pit (VIP) latrines, and facilities connected to septic tanks.[61] Similarly, for Tanzania, in 2015, 1 percent of urban households had their own toilet connected to a sewer, but 37 percent had improved provision.[62] Such statistical discrepancies obfuscate important factors that impact the health and well-being of the urban population—such as population density, topography, drinking water source, regulatory environment, and cost. Table 2 shows how the proportion of urban population with sanitation varies depending on the definitions that are used.

Table 1 | **The Joint Monitoring Programme (JMP) Service Ladder and Different Categories for Sanitation**

SOURCE TYPE	JMP SERVICE LADDER	DEFINITION
Improved: ▶ Includes flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets, or pit latrines with slabs.	Safely managed	Use of improved sanitation where human excreta are safely disposed of on-site or transported and treated off-site and not shared with other households.
	Basic	Use of improved sanitation facilities that are neither safely managed nor shared with other households.
	Limited	Use of improved sanitation facilities that are not safely managed and are shared between two or more households.
Unimproved	Unimproved	Pit latrines without a slab or platform, hanging latrines, or buckets.
Open defecation	Open defecation	No facilities; disposal of human feces in fields, forests, bushes, open bodies of water, or other open spaces or with solid waste

Note: *Improved sanitation* is more likely to ensure hygienic separation of human excreta from human contact, but it includes a range of sanitation services that are inappropriate for the urban context.

Source: Adapted from WHO and UNICEF, 2017: 8.

Table 2 | **Proportion of Urban Population with Provision for Sanitation When Applying Different Standards, 2015**

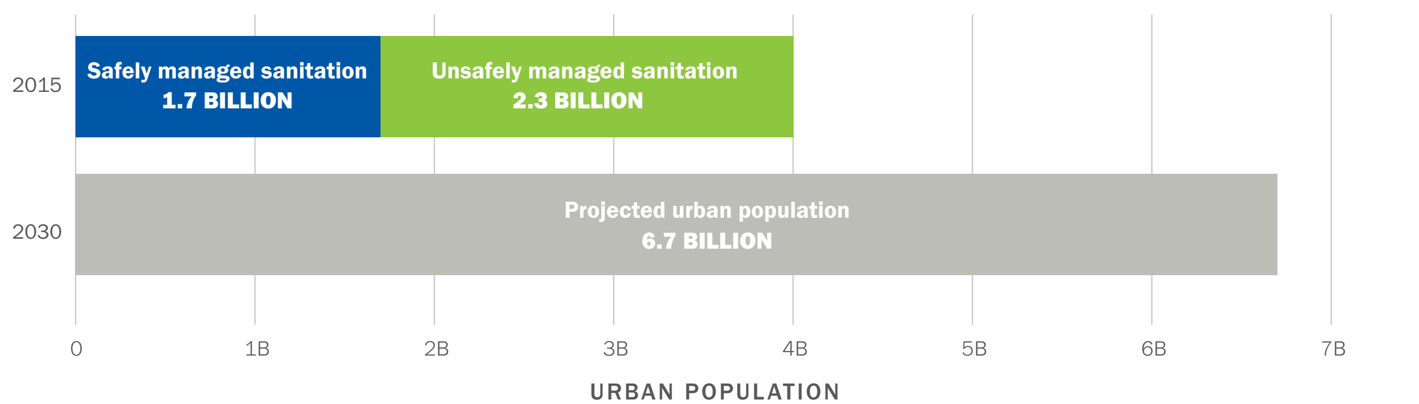
REGION	OPEN DEFECATION	UNIMPROVED	BASIC	SEPTIC TANK	SEWER CONNECTION	SAFELY MANAGED
Central Asia and Southern Asia	5	7	69	25	28	_
Eastern Asia and South-eastern Asia	1	5	87	17	59	50
Latin America and the Caribbean	1	4	90	13	72	27
Northern America and Europe	0	1	98	4	92	87
Oceania, excluding Australia and New Zealand	3	14	75	34	26	_
Sub-Saharan Africa	8	19	41	10	11	_
Western Asia and Northern Africa	0	2	93	7	76	46
Least developed countries[a]	5	22	46	13	7	_
WORLD	2	5	83	14	60	43

Notes: There is overlap between these categories.
a. The category "least developed countries" includes Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, São Tome and Príncipé, Senegal, Sierra Leone, Solomon Islands, Somalia, South Sudan, Sudan, Timor-Leste, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen.

Source: WHO and UNICEF, 2017: 57, 106.

As Table 2 shows, 43 percent of the world's urban population has safely managed sanitation, which refers to improved sanitation with excreta treated on-site or removed and treated off-site.[63] The situation looks better for basic provision: 83 percent of the world's urban population has this level of service, but this is a very low standard. The proportion of the urban population connected to sewers varies; it is 92 percent for the "Northern America and Europe" region, 72 percent for "Latin America and the Caribbean," 76 percent for "Western Asia and Northern Africa," 11 percent for "sub-Saharan Africa," and 7 percent for the "least developed countries." Sub-Saharan Africa and the least developed countries also have the highest proportion of urban population with unimproved sanitation, and they are among the highest proportion practicing open defecation. If we compare these 2015 statistics with those from 2000, we find that the number of urban dwellers lacking safely managed sanitation actually went up: from 1.9 billion in 2000 to 2.3 billion in 2015 (see Figure 3).[64]

Figure 3 | **Meeting sanitation needs will continue to be a challenge given projected urban population growth**



Note: The figure is a global estimate. It can be assumed that the proportion of urban residents without sanitation is higher in the global South.

Sources: WHO and UNICEF, 2017; UN DESA, 2018.

It must be noted that the regional groupings mask inequality within regions, particularly for the two sets of Asian countries. For example, the "Central Asia and Southern Asia" region includes, among other countries, Afghanistan, India, Iran, Nepal, and Sri Lanka, which range from low-income to upper-middle-income according to the World Bank's classification. Similarly, the region of "Eastern Asia and South-eastern Asia" includes, but is not limited to, countries with such diverse levels of economic development as Cambodia, China, Indonesia, Japan, Myanmar, the Republic of Korea, and Singapore. To observe country-level differences, one must look at subregional-level JMP data.[65]

In many urban contexts, the most appropriate sanitation solution is for two or three adjoining households on the same plot or compound to share toilets.[66] The 2017 JMP report states, "While universal use of private toilets accessible on premises remains the ultimate goal, high-quality shared sanitation facilities may be the best option in the short term in some low-income urban settings."[67] This same report introduced this as a new category—"limited"—defined as use of improved facilities that are shared between two or more households. The categorization of all shared toilets as limited is problematic given the evidence on the contribution of well-constructed community-managed toilets in addressing the need for urban sanitation services.[68]

The JMP is now planning to report on menstrual facilities as well as gendered access to toilets in nonhousehold settings.[69] It is currently updating its reporting to include data on water, sanitation, and hygiene in health care facilities and schools. The definition of *basic sanitation* will be expanded to include facilities specifically for women and girls and provide for menstrual hygiene management.[70] Box 2 highlights the sanitation needs of women and girls.

Globally, wastewater and fecal sludge treatment data have only recently been collected. Data from the Demographic and Health Survey (DHS) (on which the JMP is based in many nations) and many other national sample surveys have increased the scope and detail of questions asked regarding sanitation. However, data are still lacking regarding the spatial distribution of

Box 2 | Sanitation Needs and Challenges for Women and Girls

Deficiencies in urban sanitation usually impact women more than men because women are often responsible for managing household-level water and sanitation needs, which include cleaning private or shared toilets.[a] It also results from the fact that women have an additional need for privacy during menstruation.[b] Recent studies have explored the longstanding reluctance to discuss menstrual hygiene management, particularly its potential negative consequences on school attendance and employment.[c]

The issues of sanitation access and personal safety also disproportionately impact women and girls where residents rely on community or public facilities that have poorly lit paths or are otherwise difficult to access at night, resulting in an increased risk of sexual harassment and assault.[d] In some settlements, it is considered too dangerous to use an outside latrine located within the plot at night, so pots are used indoors.[e] In some places, residents and community organizations are addressing these issues themselves—for instance, through community policing or by going to the toilet in groups.[f]

Interviews with women who live in urban informal settlements also revealed other challenges, such as the issue of men insisting that they deserve priority access to toilets.[g] A large community-managed toilet program in Mumbai addressed the problem of men jumping ahead in line by having separate facilities with separate lines for men and women.[h] Despite advances, data deficiencies about these topics persist, which limits the development of gender-sensitive policies and practices.

Notes:
a. For more examples, see O'Keefe et al. (2015). b. Ray, 2007; Tilley et al., 2013. c. Sommer et al., 2013; Hennegan and Montgomery, 2016.
d. Amnesty International, 2010; Jagori and UN Women, 2011; Nallari, 2015; Estrin, 2018. e. Sommer et al., 2013. f. Roy et al., 2004; Nallari, 2015.
g. Bapat and Agarwal, 2003. h. Burra et al., 2003.

sanitation access in each urban area because national surveys have sample sizes that are too small to provide relevant information about a particular city. In addition, conditions in informal settlements are often underrepresented in surveys.[71]

To galvanize action, urban change agents need city and sub-city level data on sanitation practices and service provision at each step of the sanitation service chain. A persistent challenge to collecting such data is that on-site sanitation practices are largely at the discretion of the household, and in cities where large parts of the urban fabric are constructed informally and the sanitation infrastructure is subterranean, it is very difficult to assess the appropriateness and safety of construction and maintenance. Neither the DHS nor the JMP currently provides this information.

Potential opportunities to collect more detailed urban sanitation data could include national censuses. Census data should be collected from every household and can be disaggregated to the block and ward level, but censuses are expensive and are usually only conducted every 10 years. Another limitation of census data is that households usually cannot report on what happens downstream from their toilet or sanitation facility. Another source of useful data, specifically on health outcomes, could be vital registration systems and patient records from hospitals and health care clinics. Vital registration systems should provide detailed data for each locality regarding deaths and their causes, and they have the potential to connect these to the prevalence of waterborne or water-related diseases. However, in many global South cities, vital registration systems do not function well. In addition, there may be no existing system with which to monitor and utilize relevant data from patient records at hospitals and health care centers, which impedes authorities' ability to respond to sanitation-related health problems.[72]

Along the entire sanitation chain, there is a dearth of data for individual cities on the proportion of population with quality sanitation. It is important to acknowledge there have been serious efforts to estimate sanitation in particular cities (such as the SFDs discussed earlier) as well as more local studies; however, as mentioned, these efforts suffer from similar limitations, such as the difficulty of designing surveys that capture what happens downstream from toilets and the challenges associated with investigating the quality of on-site subterranean sanitation construction and maintenance.[73]

In sum, three limitations make it difficult to accurately understand the risk that current sanitation practices pose to urban populations:

1. The UN category of "improved" sanitation captures such a wide variety of sanitation practices that it does not provide a useful picture of the health and environmental risks in urban areas.

2. The JMP categories fail to address affordability from the perspective of the household, especially low-income households.[74]

3. There is missing city and sub-city level data about sanitation practices and management at different stages of the service chain, and even less information about sanitation in informal settlements.

Consensus on the SDGs, as well as efforts to harmonize data collection and aggregate data to monitor progress towards these goals, is important and deserves support. This discussion is intended to make these efforts more meaningful to urban change agents who are working towards improving urban sanitation services and conditions. At present, however, the lack of reliable city and sub-city level data about urban sanitation practices and access inhibits meaningful action.

To galvanize action, urban change agents need city and sub-city level data on sanitation practices and service provision at each step of the sanitation service chain. A persistent challenge to collecting such data is that on-site sanitation practices are largely at the discretion of the household, and in cities where large parts of the urban fabric are constructed informally and the sanitation infrastructure is subterranean, it is very difficult to assess the appropriateness and safety of construction and maintenance.

4. SANITATION CONDITIONS AND PRACTICES IN 15 CITIES

In the absence of comparable city-level sanitation data, we used a consistent methodology to compile, collect, and analyze data in 15 cities in sub-Saharan Africa, South Asia, and Latin America, which are the regions that are the focus of the *WRR Towards a More Equal City*. The 15 cities include Kampala, Uganda; Lagos, Nigeria; Maputo, Mozambique; Mzuzu, Malawi; Nairobi, Kenya; Bengaluru, India; Colombo, Sri Lanka; Dhaka, Bangladesh; Karachi, Pakistan; Mumbai, India; Caracas, Venezuela; Cochabamba, Bolivia; Rio de Janeiro, Brazil; Santiago de Cali, Colombia; and São Paulo, Brazil (see Figure 4).

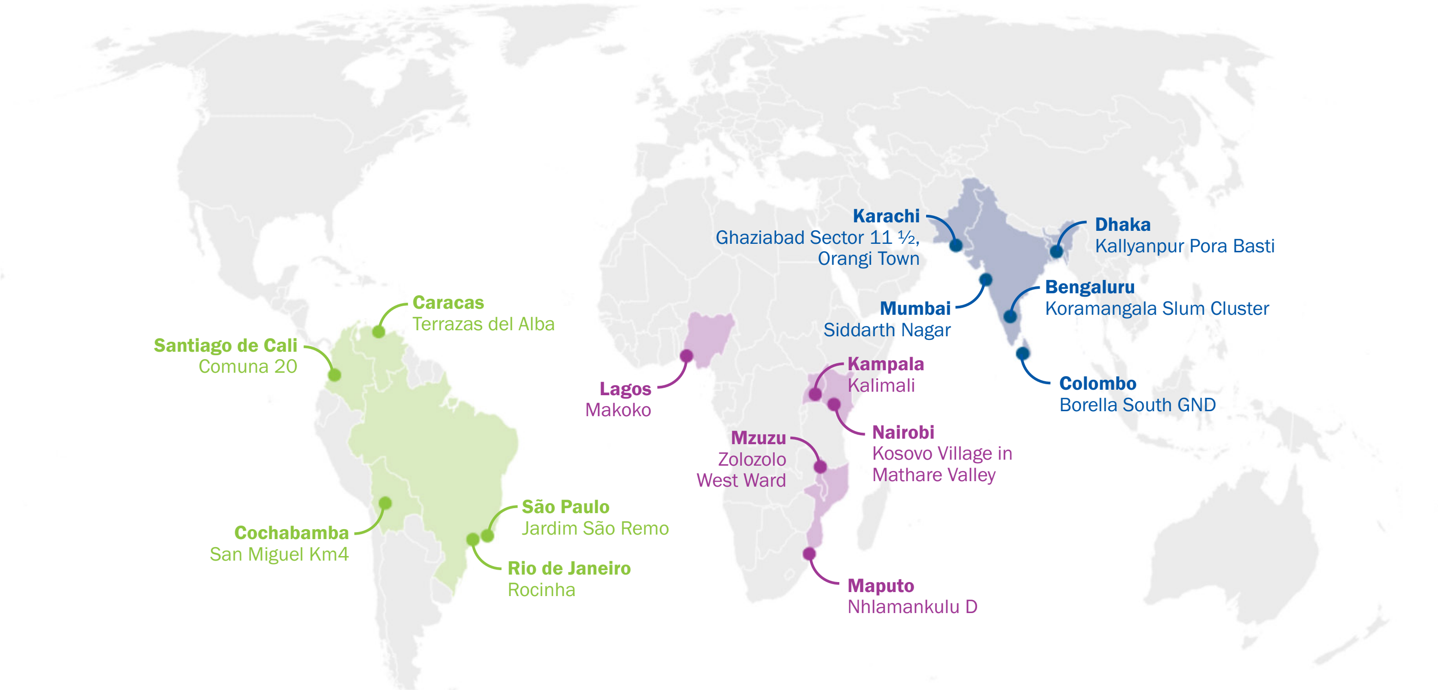
Based on the city classifications introduced in the WRR—*struggling*, *emerging*, *thriving*, and *stabilizing*—all the cities in Asia and Africa were either struggling or emerging (see Figure 5).[75] Three of the cities in Latin America—Caracas, Rio de Janeiro, and São Paulo—were *thriving*, which reflects the region's more advanced stage of urbanization and economic development. At the time the cities were classified in 2016, Caracas was just above the *emerging* city threshold; however, the economic and political situation in Caracas has since declined.

Research Strategy and Methods

To create a data set for each city, we collaborated with local researchers who had a minimum of seven years' experience in the water and sanitation sector. Data were obtained from interviews, fieldwork, publicly available data sets, administrative records, websites, and project documents. Researchers in each city conducted an average of seven key informant interviews. Data were collected on household sanitation practices and access to facilities; citywide sanitation infrastructure, cost of on-site sanitation construction, and fecal sludge removal; fees for piped sewage; the lining of pit latrines; and proximity of septic tanks and pit latrines to water sources.

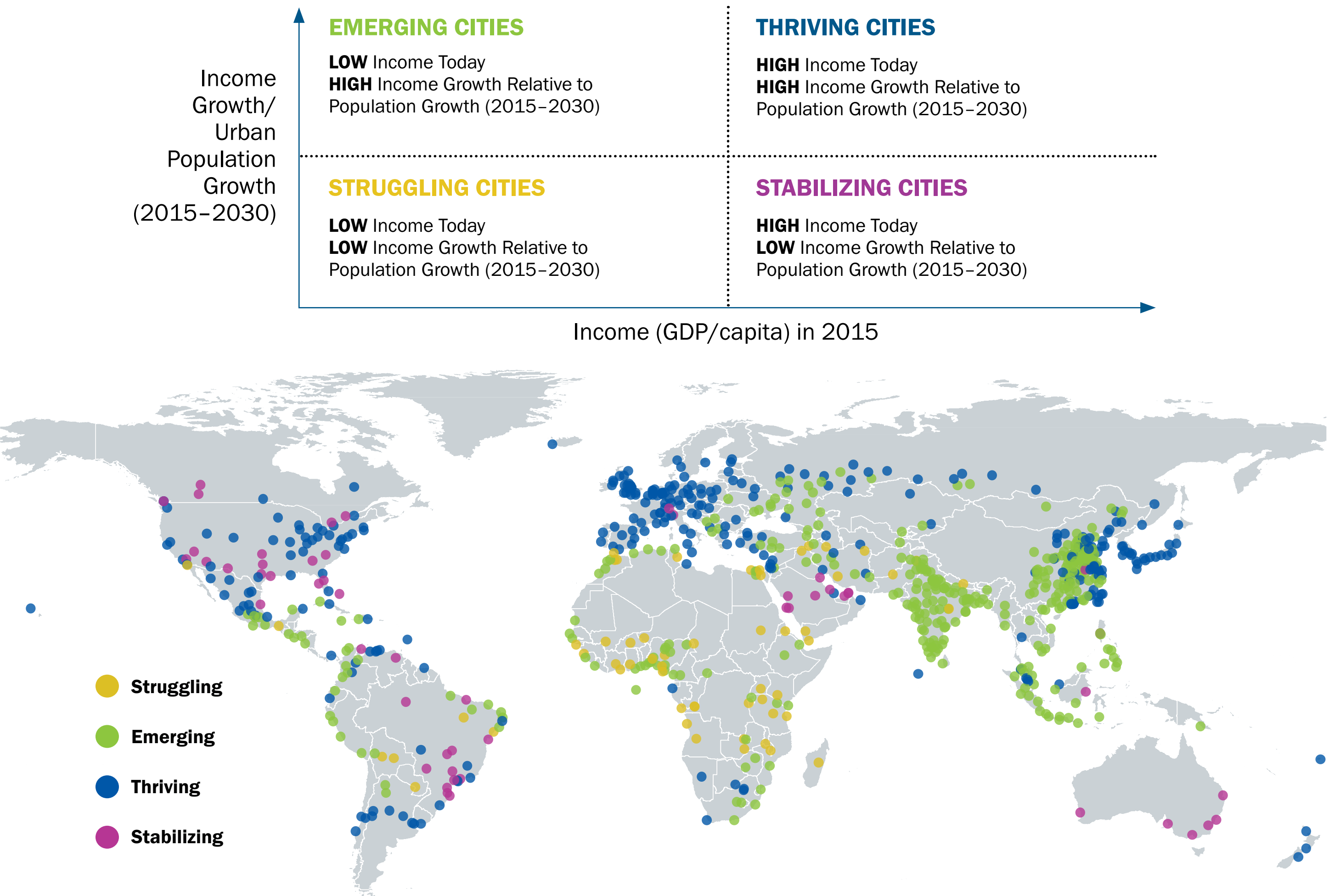
In addition to the city-level data, we conducted fieldwork in one informal settlement or low-income neighborhood in each of the 15 cities.[76] We added this "case within the case" for two reasons: (1) city-level data is usually presented in averages and thus tends to mask extremes at both ends of the socioeconomic distribution, and (2) in many cities, informal settlements or low income neighborhoods are excluded from or are underrepresented in formal city-level statistics. To select the "case within the case" in each city, the researchers identified a centrally located, well-established settlement that did not represent either the city's "best" or "worst" conditions but rather common conditions in other informal or low-income settlements in the city.

Figure 4 | **The 15 cities and informal settlements where sanitation data were collected**



Source: WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

Figure 5 | **World Resources Report city categories**



Source: Beard et al., 2016, based on data from Oxford Economics, 2016.

In addition to the city-level and informal settlement data, each researcher wrote a narrative supplement that described the city's land-use patterns, patterns of sanitation services access, the rationale for selecting the informal settlement, a description of the institutional landscape of sanitation provision, and an overview of unique contextual factors important for understanding sanitation access. Examples of unique contextual factors include community-constructed sewage lines in Karachi; how a public-private partnership affected sanitation services in parts of Rio de Janeiro; how the Swachh Bharat program in Mumbai sought to eliminate open defecation through the provision of community toilets; and how the high density in Dhaka and a high water table in parts of Lagos made on-site sanitation difficult, despite the fact that pit latrines and septic tanks are commonly used in both cities. In short, each of the 15 cities had unique circumstances that were important for interpreting the data.

Our data address some of the limitations of the global and national sanitation data discussed earlier by augmenting it with fieldwork in one informal settlement and a qualitative narrative. However, our data suffer from some of the same challenges mentioned earlier. First, some information was collected from households that have a limited understanding of what happens to their waste downstream. Second, there is limited reliable, systematic data about households' construction of on-site sanitation systems. Approximately 45 percent of residents in the 15 cities live in informal settlements, where much of the sanitation infrastructure is constructed without documenting construction materials, construction specifications, and maintenance practices. Table 3 provides an overview of these 15 cities and 15 informal settlements that form the basis of our data.

Table 3 | A Snapshot of the 15 Cities and Selected Informal Settlements

					CITY					
Region	CITY NAME	COUNTRY	WRR CITY CATEGORY	TYPE OF JURISDICTION	POPULATION	AVERAGE HOUSEHOLD SIZE	URBAN DENSITY (PEOPLE/ SQ. KM)	% OF WORK-FORCE IN INFORMAL ECONOMY	% OF HOUSE-HOLDS IN INFORMAL SETTLEMENT	AVG HOUSEHOLD INCOME/ MONTH (US$)
SUB-SAHARAN AFRICA	**Kampala**	Uganda	Struggling	City	1,507,080	4.0	7,974	70	60	124
	Lagos	Nigeria	Struggling	Metropolis	23,300,000	5.0	19,898	70	70	218
	Maputo	Mozambique	Emerging	Municipality	1,194,121	4.9	3,431	55	9	162
	Mzuzu	Malawi	Struggling	City	254,891	5.0	1,770	80	60	91
	Nairobi	Kenya	Struggling	City county	4,397,073	3.2	6,421	53	65	213
SOUTH ASIA	**Bengaluru**	India	Emerging	Municipality	8,443,675	4.0	11,395	60	30	668
	Colombo	Sri Lanka	Emerging	Municipality	555,031	6.1	15,001	38	44	549
	Dhaka	Bangladesh	Emerging	City corporation	6,970,105	4.4	22,778	75	23	653
	Karachi	Pakistan	Emerging	Municipality	16,054,988	6.0	12,350	70	52	330
	Mumbai	India	Emerging	Municipal corporation	12,442,373	4.5	27,167	80	40	244
LATIN AMERICA	**Caracas**[a]	Venezuela	Thriving	Municipality	3,319,849	3.7	4,216	28	60	1803
	Cochabamba	Bolivia	Struggling	Municipality	632,013	3.0	1,612	55	27	210
	Rio de Janeiro	Brazil	Thriving	Municipality	6,320,446	3.0	5,263	35	23	475
	São Paulo	Brazil	Thriving	Municipality	12,040,000	3.2	7,916	20	12	1083
	Santiago de Cali	Colombia	Emerging	Municipality	2,278,022	4.0	3,680	60	23	437

Table 3 | **A Snapshot of the 15 Cities and Selected Informal Settlements (continued)**

INFORMAL SETTLEMENT				
SETTLEMENT NAME	POPULATION	AVG. HOUSEHOLD SIZE	URBAN DENSITY (PEOPLE/ SQ. KM)	AVERAGE HOUSEHOLD INCOME/MONTH (US$)
Kalimali	1,540	5.0	48	48
Makoko	204,720	5.0	96,566	195
Nhlamankulu D	12,175	5.1	2,202	130
Zolozolo West Ward	21,349	5.0	10,215	81
Kosovo Village in Mathare Valley	12,000	3.0	120,000	81
Koramangala Slum (Resettlement) Cluster	38,500	4.5	140,000	179
Borella South	5,127	4.2	754	503
Kallyanpur Pora Basti	11,357	3.9	227,140	171
Ghaziabad Sector 11 ½, Orangi Town	51,000	8.0	78,462	273
Siddarth Nagar	2,160	4.2	—	202
Terrazas del Alba	3,500	3.5	35,000	1075
San Miguel Km4	1,705	6.0	131	168
Rocinha	77,178	3.0	90,798	378
Jardim São Remo	6,930	3.5	86,500	410
Comuna 20	68,980	4.0	—	195

Notes: Figures for population, households, and average household size are based on national statistics. Figures for percentage of workforce in informal economy, households in informal settlements, and average household incomes were locally determined. These figures came from a combination of key informants, project reports, and government records. For U.S. dollars, local currency figures were converted using market exchange rates from the time of data collection (2018).

a. Caracas has variable inflation rates. Costs were converted using the exchange rate during the year of data collection: 2012 (Bs4.30 to US$1). At the time the cities were classified in 2016, Caracas was just above the emerging city threshold and categorized as "thriving." However, the economic and political situation in Caracas has since declined.

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[77]

Each region featured cities of different sizes. Note that population size pertains to the municipality and not the metropolitan area, which usually covers a larger land area.[78] Despite this, the city's jurisdiction is important because the data in subsequent tables is based on these boundaries. As discussed earlier, population density is particularly relevant when considering different sanitation service options, and our samples covered a broad range of city densities, from 1,612 people per square kilometer in Cochabamba to 22,778 people per square kilometer in Dhaka.

In six cities, more than half of all households exist in informal settlements. In Mumbai, 40 percent of households are in informal settlements, and this percentage would be higher if the entire metropolitan area were considered rather than just the municipality. Consistent with the findings of the WRR working paper on informal work, the lowest levels of workforce informality are found in Latin America, compared to larger proportions in South Asia and sub-Saharan Africa.[79] Data from informal settlements provide insight into urban sanitation access usually not captured in data about the formal city. Consistent with the reality of many global South cities, most of these settlements are diverse and heterogeneous; population size and number of households vary widely.

What Sanitation Facilities Do Households Use?

Access to sanitation starts with having a place—a sanitation facility— in which to dispose of human waste. Private sanitation facilities are located inside a house or on the house plot and are not shared. Shared sanitation facilities are privately managed and shared by more than one household. Communal or public sanitation facilities are managed by a range of actors, including communities, nongovernmental organizations (NGOs), and local governments. Households categorized as having no sanitation facilities dispose of their fecal matter in open spaces or engage in other forms of open defecation. Figure 6 describes household access to sanitation facilities at the city level and in the profiled informal settlement.

The highest percentage of households with a private sanitation facility was found in Santiago de Cali, Caracas, Cochabamba, and São Paulo, at 99–100 percent. The lowest percentages, less than a third, were found in Kampala, Lagos, and Nairobi. For shared toilets, the highest percentages were 72 percent in Lagos, 60 percent in Kampala, and 51 percent in Mzuzu, all cities in which many residents rent space in compounds that have shared facilities.[80]

Of the 15 informal settlements, the percentage of households with a private sanitation facility was 100 percent in 4 settlements: Caracas, Cochabamba, Karachi, and São Paulo.[81] This figure was 99 percent in settlements in Santiago de Cali, 97 percent in Rio de Janeiro, and 93 percent in Colombo. The percentage with shared sanitation was highest in our selected informal settlements in Nairobi (85 percent) and Lagos (65 percent).

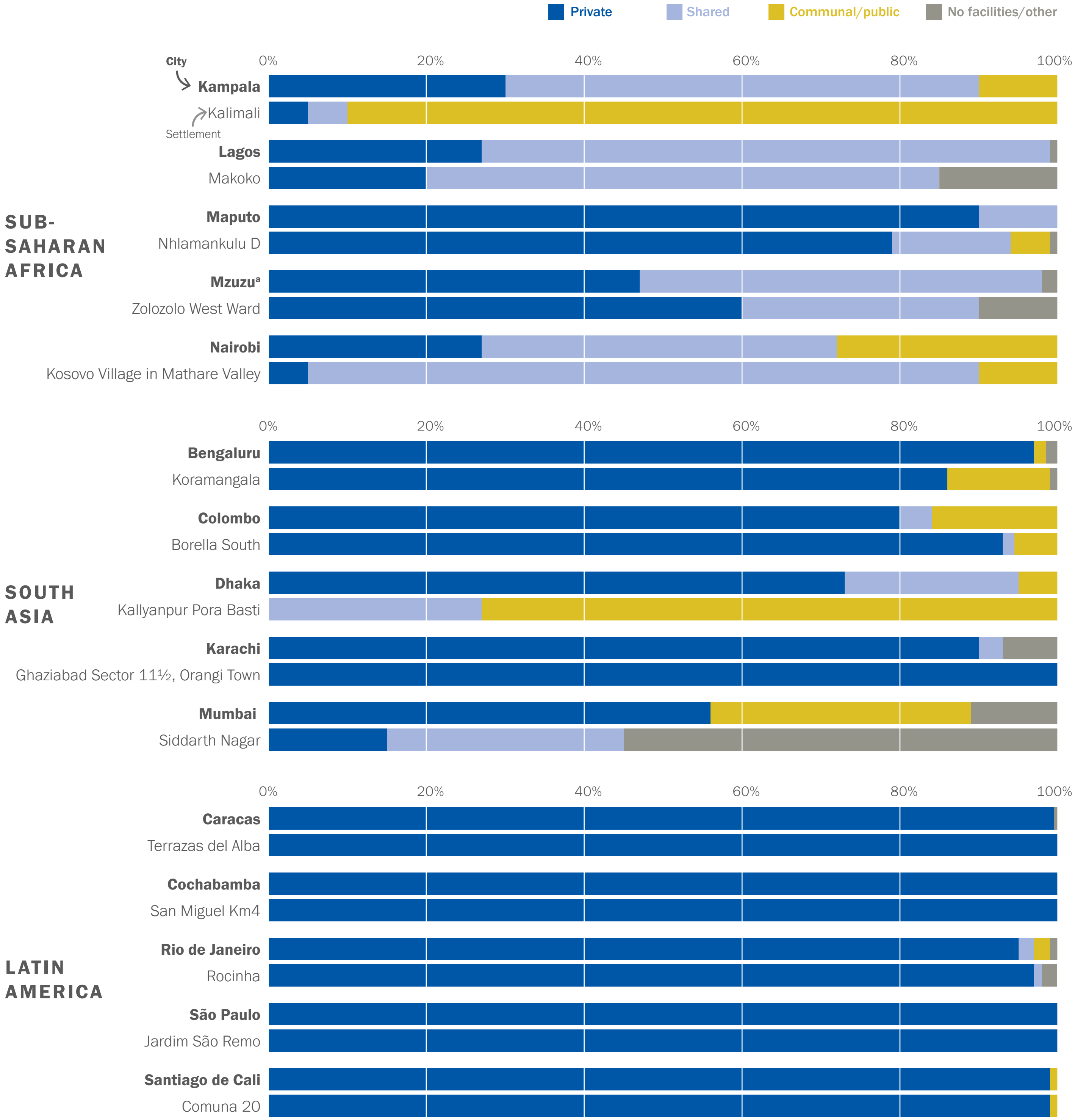
In the informal settlements, the percentage of households without access to facilities was highest in Mumbai, at 55 percent, and 10–15 percent in informal settlements in Mzuzu and Lagos, respectively. This is consistent with our findings that cities in South Asia and sub-Saharan Africa had the highest rates of open defecation. Sanitation service provision in informal settlements differs considerably based on a variety of factors, including when the neighborhood was established, landownership, residential density, the location of the settlement, the availability of land, the extent to which standards and regulations are enforced, and collective practices.

How Do Households Manage Urban Sanitation?

Within cities and even within informal settlements, households dispose of human waste in different ways, which include the use of sewers, private or communal septic tanks, various types of pit latrines, composting toilets, buckets, hanging toilets, smaller forms of containment, open defecation, and self-provisioned drains. Although septic tanks and pit latrines can hold waste for longer periods of time, they need to be carefully emptied. On the other hand, self-provisioned drains, hanging toilets, and other informal types of containment usually result in untreated waste being frequently disposed of directly into the local environment. Figure 7 describes households' access to these various disposal methods at the city level and in one informal settlement.

As is true of other categories, household access to sewers ranges widely in all three regions. Only Santiago de Cali and São Paulo reported having water available continuously, 24 hours per day seven days per week.[83] Bengaluru reports that 79 percent of households use sewers, but water is only available on average for three hours, three days a week across different locations in the city.[84] In cities in sub-Saharan Africa, the percentage of households with access to sewers was the lowest, ranging from between 10 percent in Kampala to 0 percent in Lagos and Mzuzu. In the event of intermittent water supply, sewers will not function properly and there will be an increased risk of contaminating the piped water supply.[85]

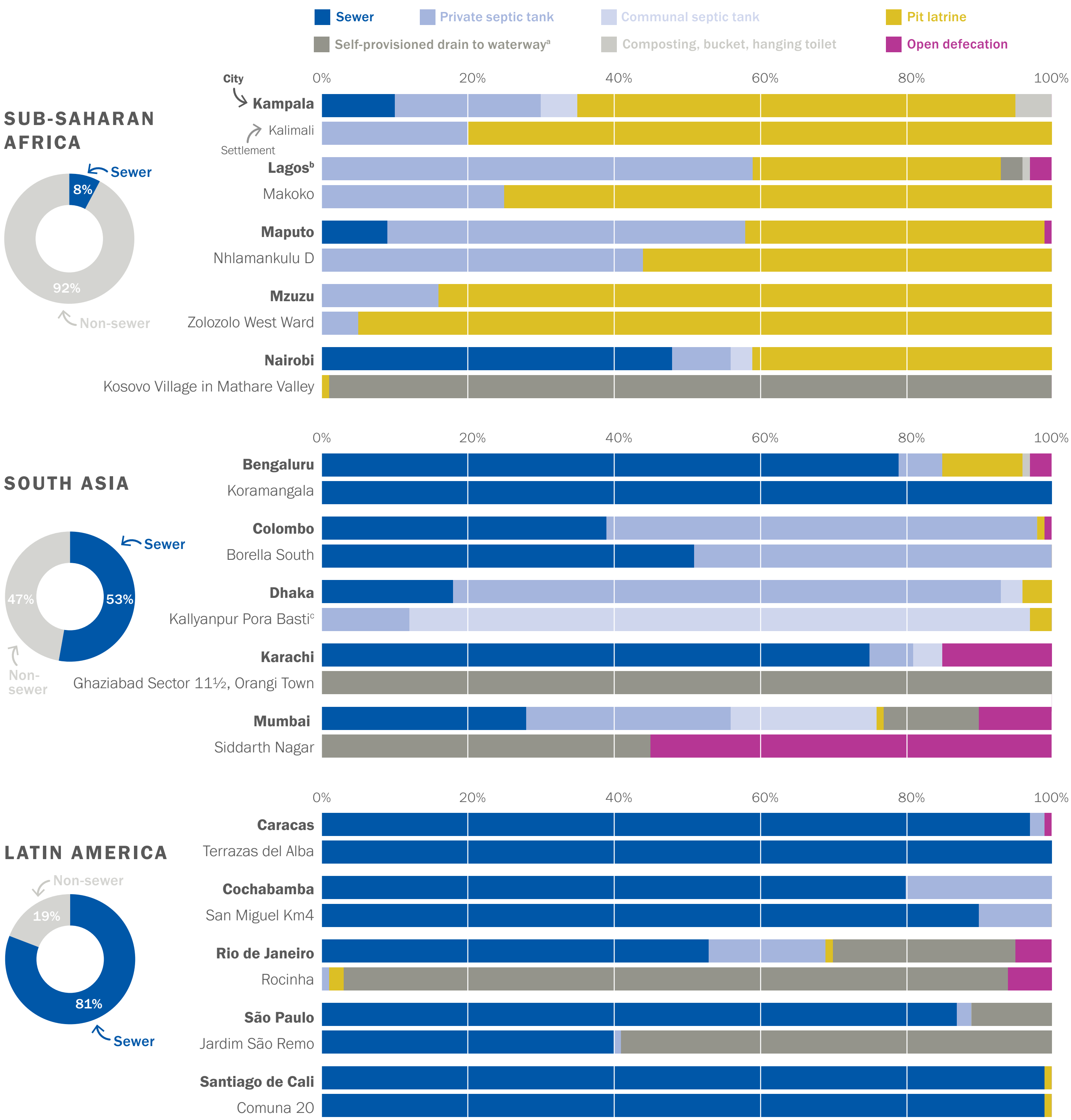
Figure 6 | **Household access to different types of urban sanitation facilities (citywide and informal settlement)**



Note: a. Based on key informant estimates derived from a study limited to three communities.

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

Figure 7 | **Household urban sanitation management practices (citywide and informal settlement)**



Notes:

a. Estimates of fecal sludge disposal using "self-provisioned drain to nearby waterway" are more accurate for the informal settlements because enumerators conducted field research and direct observation in these settlements.

b. Although categorized as pit latrines, the majority of these are self-provisioned pits and unlined pits.

c. According to key informants, more than 80 percent are septic tanks without soak pits and are directly connected to storm water drainage.

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[82]

Private septic tanks are reportedly a main alternative for many cities with lower rates of household sewer connection. They serve 75 percent of households in Dhaka, 59 percent in Lagos, 59 percent in Colombo, and 49 percent in Maputo. However, it is important to qualify that many of these receptacles are not properly functioning septic tanks. For example, key informants from Dhaka reported that more than 80 percent of these "septic tanks" do not have soak pits and directly connect to drainage. This is consistent with a 2016 study that reported that half of Dhaka's households use a "sealed box [that] discharges to the drainage system."[86] In sub-Saharan African cities, pit latrines are an important mechanism for immediately disposing of human waste; for example, in Mzuzu and Kampala, 84 percent and 60 percent of households use pit latrines, respectively. Several field interviews also highlighted the low quality of pit latrine construction, emptying practices, and schedules, and, as a result, their overall inability to prevent contamination. Risks may be especially high where households rely on nearby groundwater sources for domestic water use, especially from shallow and unprotected wells.

In cities in the global South, human waste is often disposed of using a self-provisioned drain directly connected to a nearby waterway or storm water drainage channel. Enumerators in Bengaluru, Caracas, Cochabamba, Colombo, Kampala, Karachi, Lagos, Nairobi, and Santiago de Cali all acknowledge that self-provisioned drains exist, but there is no reliable way to estimate the percentage of households that use them at the city level. Dhaka has self-provisioned drains, but these are primarily used in the urban periphery. Maputo and Mzuzu do not have self-provisioned drains because households mainly use on-site sanitation. Some self-provisioned drains function as open sewers and are likely included in sewer estimates, thus leading to an overestimation of how many households have sewer access.

Composting, bucket, and hanging toilets are used by 5 percent of households in Kampala and 1 percent of households in Lagos and in Bengaluru. Open defecation is practiced in cities in all three regions, but it is most common in Karachi (15 percent) and Mumbai (10 percent).

In the informal settlements where we conducted field research, 9 out of 15 settlements—including those in Dhaka, Karachi, Mumbai, Rio de Janeiro, and in all the sub-Saharan African cities—did not have access to sewer infrastructure. There is also a discrepancy between the number of informal settlements that reported that 90–100 percent of households are connected to sewers, such as those in Bengaluru, Caracas, Cochabamba, and Santiago de Cali, because sewers need daily water supplies to function properly, yet only the one in Santiago de Cali has access to continuous piped water 24 hours per day seven days per week.[87] Based on field observations in African cities, problems accessing sanitation are particularly acute for renters because landlords commonly shut off access to waterborne sanitation when water is not available.

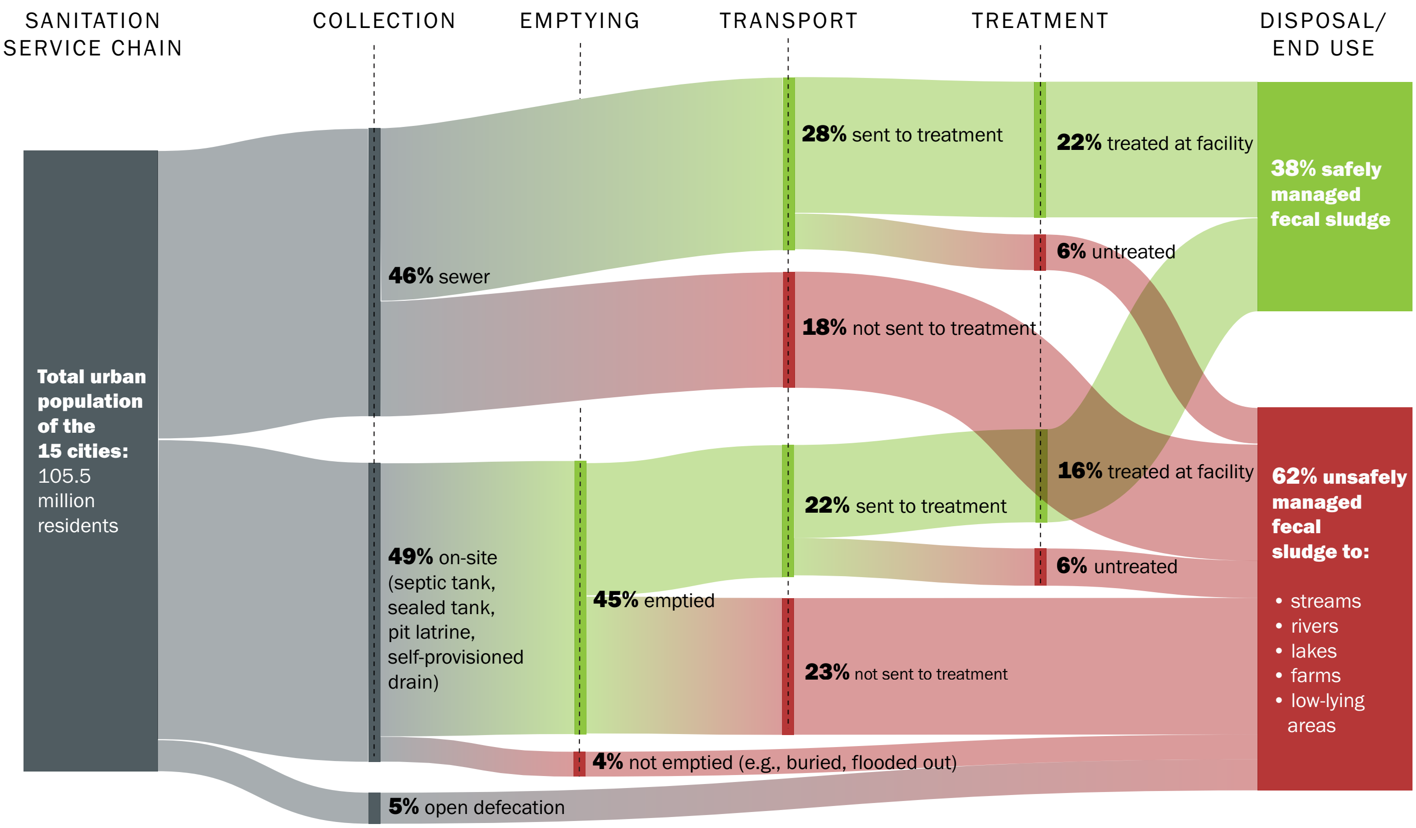
Households in informal settlements also use private septic tanks, with the highest rates found in Colombo (49 percent) and Maputo (44 percent). In Dhaka's informal settlement, 85 percent of households rely on communal septic tanks, but many of these do not have proper soak pits. Similar to the city-level findings, in four out of the five sub-Saharan African informal settlements, households rely on pit latrines. Self-provisioned drains are also widely used in the informal settlements in Karachi, Mumbai, Nairobi, Rio de Janeiro, and São Paulo. Open defecation was only found in two informal settlements, Mumbai (55 percent) and Rio de Janeiro (6 percent).

What Happens to Human Waste?

Figure 8 presents the sanitation service chain for all 15 cities, including off-site and on-site systems. To review, *off-site sanitation* refers to the use of sewer technology to convey human waste away from the home or plot, and *on-site sanitation* refers to the containment of human waste on the plot and includes septic tanks, pit latrines, and container-based sanitation. We also include self-provisioned drains, buckets, composting toilets, and hanging latrines in the on-site category.

In geographic terms, patterns of access to sewers and fecal sludge treatment follow national-level data for urban areas, with high percentages in Latin America, lower percentages in South Asia, and the lowest percentages in sub-Saharan Africa. Two cities in sub-Saharan Africa, Lagos and Mzuzu, have no sewers. An extreme situation is found in Caracas, where 97 percent of human waste is conveyed via sewer and 0 percent is sent to a treatment plant. Another finding is that although many sewage systems collect human waste, there is wide variation in how much of it is treated. For example, in Cochabamba, 80 percent of human waste is collected by a sewer system, but only 48 percent is delivered to a treatment plant (the remaining 32 percent is discharged to open surface water bodies). There is also a discrepancy between how much human waste is sent to the treatment plant and how much is actually treated because treatment plants are overwhelmed or not functioning properly. This was found in cities in all three geographic regions. Also relevant is that water is only available continuously in four cities and 20 hours a day, seven days per week in two more cities; in

Figure 8 | **In 15 global South cities, 62 percent of fecal sludge is unsafely managed**



Notes: The percentages are weighted by the population. In the Appendix, see Table A.1 for utility-level treatment information and Table A.2 for city-level data on the sanitation service chain.

Source: Authors' analysis, based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

four cities, there are days each week in which water does not flow at all. In eight informal settlements, water is not available every day of the week.[88] The availability of water is relevant because sewers do not function properly without water.

The amount of on-site sanitation that is not emptied (4 percent) seems low given the qualitative information we have about the 15 cities. This might be explained by the fact that "flooding out" pit latrines is an informal coping mechanism used by households and against sanitation regulations in cities where they exist and therefore not captured by surveys. In contrast, there are other cities where a large number of households use on-site sanitation and the percentage of human waste that is safely managed is higher than the percentage of households connected to sewers. For example, in Mumbai, 28 percent of households are connected to sewers, yet 56 percent of human waste is safely managed; in Kampala, only 10 percent of households are connected to sewers, yet 29 percent of human waste is safely managed; in Lagos, 0 percent of households are connected to sewers, and 45 percent of human waste is safely managed.[89] This underscores the important work of local authorities in safely managing and treating fecal sludge from on-site sanitation methods.

What Is the Risk of On-Site Sanitation Contaminating Household Water Supplies?

As mentioned earlier, the percentage of households at the city level that rely on pit latrines is highest in the sub-Saharan African cities, ranging from 40 percent in Nairobi to 84 percent in Mzuzu. In the informal settlements included in the study, the number of households relying on septic tanks range from 5 percent in Mzuzu to 97 percent in Dhaka. In all of the informal settlements except Cochabamba, the septic tanks were located less than the recommended 50 meters (m) from a groundwater or surface water source.[90] In the informal settlements, the percentage of households that use pit latrines ranges from 1 percent in Nairobi to 95 percent in Mzuzu. Finally, in Bengaluru, Kampala, Karachi, Lagos, Maputo, Mumbai, and Nairobi, a substantial proportion of the population, between 8 and 69 percent, relies on groundwater or surface water, thus increasing their risk of contamination from on-site sanitation practices (see Table A.3 for information on septic tank and pit latrine proximity to water sources).

Our study shows how the scale and range of sanitation practices vary widely. Some informal settlements have better sanitation provision than that assessed for the average population at the city level. This is largely a result of the settlements' central location and in some cases the presence of active civil society organizations that facilitate sanitation services. The findings demonstrate a geographic pattern of access to different urban sanitation services. They also underscore the very large range in the price, quality, and effectiveness of sanitation options available to households and the associated risks to the whole city.

What Do Households Pay for Sanitation?

The cost of sanitation is closely related to the question of equitable access.[91] When households do not have access to a public sewer connection, they often pay to provide their own on-site sanitation. Table A.4 shows the cost of constructing and emptying various on-site sanitation options in the 15 cities and respective informal settlements.

In summary, there is wide variation in the cost of septic tank construction and emptying. Some of the differences are explained by differences in construction, the size of the tank, the quality of materials used, and the ground where the tank is installed. The average cost of building a household septic tank in Karachi is approximately $165; compare this to Nairobi, where a conventional concrete tank costs around $1,987, but a smaller plastic "biodigester" tank is $662. Because most private tanks are constructed at the direction of the household, often they are not properly constructed, so many do not include soak pits; others leak, and some drain directly into local waterways. In Dhaka, the average communal septic tank ($711) serves 5–20 families. The cost of emptying a private septic tank (per tank, per time) also varies, between $24 and $29 in Colombo and Bengaluru, respectively, to $313 in São Paulo and $565 in Karachi. Costs vary widely due to different city standards, labor costs, and materials, as well as the size and the construction of the tank itself.

In general, the cost of building a septic tank in the informal settlements was the same or lower compared to the average cost at the city level, except in Cochabamba, where it was more expensive. Two informal settlements in Latin American cities have among the lowest capital costs for building septic tanks in all of the cities we studied. Although the cost of constructing septic tanks is relatively inexpensive in Latin America, the cost of emptying them is relatively high: $210 in Cochabamba and $219 in São Paulo. In informal settlements in other cities, costs range from $8 for manual emptying in Maputo's informal settlement to $76 in Kampala's informal settlement. Again, these costs are averages and are not based on a single standard-sized tank.

In some cities where a large number of households use on-site sanitation, the percentage of human waste that is safely managed is higher than the percentage of households connected to sewers. . . . This underscores the important work of local authorities in safely managing and treating fecal sludge from on-site sanitation methods.

The cost of installing a pit latrine depends on many factors, including the social acceptability associated with different types of construction. For example, a pit latrine might consist of a shallow hole surrounded by four posts with material draped around them for privacy. Or it might be surrounded by a more substantial building that has a lockable door, a slab foundation, and a ventilation pipe. Other factors that affect cost are the materials and construction needed to fit the location's topography, water table, and geology. The most basic pit latrines with no slab are relatively inexpensive to build if the land is available; for example, $16 in Maputo, $23 in Mumbai, and $24 in Colombo and Dhaka.[92] However, one-third to one-half of residents who are tenants have no access to land and are dependent on the investments made by landowners; here, the cost is less relevant as tenants cannot choose to make the improvement. The cost of emptying a pit latrine ranges from between $10 in Kampala to $45 in various other cities.

Pit latrines are relatively inexpensive to construct in informal settlements. In Dhaka's informal settlement, they cost $36 to construct; in Maputo's settlement, it costs $16 to construct a basic pit latrine with no cement slab. Pit latrines with slabs are more expensive, usually two to four times the price of a basic pit latrine. VIPs are usually three to six times the price of a basic latrine.[93] VIPs range between $410 in Mzuzu to $1,192 in Lagos. The cost of emptying pit latrines ranges between $6 for manual evacuation in Dhaka to $96 for mechanized pump out in Kampala. This cost reflects a range of variables, from ease of access to type of technology used to remove fecal sludge. It should be noted that many households in informal settlements do not have the incentives or cannot afford to pay for these services. For example, in informal settlements in Dhaka, pits are partially emptied or "flooded out" during the rainy season. In Mzuzu, when a pit latrine is full, it is buried and a new pit is dug.

All cities in the study except for Lagos and Mzuzu had municipal sewer systems that served some proportion of the urban population. Table 4 describes the costs associated with building a sanitation facility (bathroom) in a household (including labor and materials, and excluding land costs) and connecting to the municipal sewer system. Public sewer connectivity is the proportion of households receiving sewage service out of the total number of households eligible for a sewer connection within a municipality's boundaries. In sum, our on-site sanitation cost data (see Table A.4) shows the wide range of sanitation options and the varying costs from the household perspective. In the short to medium term, most cities in the global South will provide residents with a mix of sanitation services. However, from the household perspective, on-site services are not necessarily less expensive than off-site services, and in many cases on-site services are more expensive.

Table 4 | **Costs to Construct and Connect Sanitation Facilities to Piped Sewers in Each City**

REGION	CITY NAME	SANITATION FACILITY CONSTRUCTION COSTS (US$)	AVERAGE CONNECTION FEES TO PIPED SEWERAGE (US$)	PUBLIC SEWER CONNECTIVITY RATE[a]	INFORMAL SETTLEMENT NAME	SANITATION FACILITY CONSTRUCTION COSTS (US$)	AVERAGE CONNECTION FEES TO PIPED SEWERAGE (US$)
SUB-SAHARAN AFRICA	Kampala	357 (2 toilets)	58	100%	Kalimali	NC	NC
	Lagos	NC	NC	—	Makoko	NC	NC
	Maputo	470	35	100%	Nhlamankulu D	NC	NC
	Mzuzu	NC	NC	-	Zolozolo West Ward	NC	NC
	Nairobi	104[b]	47	90%	Kosovo Village in Mathare Valley	NC	NC
SOUTH ASIA	Bengaluru	543	9	90–95%	Koramangala	543	0[c]
	Colombo	548	32	98%	Borella South	645	58
	Dhaka	593	296	100%	Kallyanpur Pora Basti	NC	NC
	Karachi	282	188	60%	Ghaziabad Sector 11 ½, Orangi Town	122	28
	Mumbai	171	124	100%	Siddarth Nagar	NC	NC
LATIN AMERICA	Caracas[d]	64	0[c]	—	Terrazas del Alba	64	0[e]
	Cochabamba	294	252	100%	San Miguel Km4	252	252
	Rio de Janeiro	612	121	100%	Rocinha	NC	NC
	São Paulo	639	109	97%	Jardim São Remo	156	63
	Santiago de Cali	224	90	87%	Comuna 20	181	86

Notes: All costs reported in U.S. dollars. Currency figures were converted to U.S. dollars using market exchange rates corresponding to the time of data collection (2017). Connection fees may vary across the city depending on distance and pipe size. Only Cochabamba, Colombo, Maputo, and Santiago de Cali had reliable data on connectivity rates. The remaining figures are based on key informant estimates. NC stands for "not connected."

a. *Public sewer connectivity rate* is defined as the proportion of households connected to the sewage network compared to those offered service within the municipal boundaries. For example, if 100 households are offered water sewage service and 50 households are connected, then the household connection rate is 50 percent.
b. This is the cost for a facility within a building already connected to the public sewer.
c. There is a wastewater tariff that is 15–25 percent of the monthly water bill, but the water and sanitation utility has given free connections to this slum for the time being.
d. Costs from Caracas were converted using the black market exchange rate during the time of data collection (Bs8,600 to US$1).
e. The connection fee to city sewerage is supposed to be charged as part of a monthly tariff by the water utility, but the utility has not included this yet.
Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[94]

The cost of building a sanitation facility ranges from as low as $64 in Caracas to as high as $612 in Rio de Janeiro. In nine cities, the price ranges from $171 to $593. Drawing on data from 12 cities, the cost per household for a sewer connection ranges from $9 in Bengaluru to $296 in Dhaka. In seven cities, the price for a municipal sewer connection is between $90 and $296. The cost of connecting to the municipal sewer system—where it is available in sub-Saharan Africa—is substantially lower, ranging from $35 in Maputo to $58 in Kampala. For public sewer connectivity, only Cochabamba, Colombo, Maputo, and Santiago de Cali had data on connectivity rates. For the remaining cities, figures are based on key informant estimates. In terms of cost of land for constructing community toilets, there are a variety of arrangements. For example, in some cases, toilets are rebuilt on the sites of failed public facilities, so the land is free.

Six of the 15 informal settlements are at least partially connected to a municipal sewer system. Only one of the five informal settlements in sub-Saharan Africa—the one in Nairobi—is connected to the municipal sewer system. The cost of constructing a household sanitation facility ranges from $64 in the informal settlement in Caracas to $645 in Colombo's informal settlement, which is comparable to citywide costs.

In the short to medium term, most cities in the global South will provide residents with a mix of sanitation services. However, from the household perspective, on-site services are not necessarily less expensive than off-site services, and in many cases on-site services are more expensive.

When analyzing costs from the perspective of the lowest-income residents, it must be recognized that sanitation often involves a relatively large one-time capital investment, unless people are buying services on a pay-per-use basis (or through a subscription to a local pay-per-use facility). For those able to access sewers, the 15-city study shows that the one-time connection and construction costs for households in informal settlements is as much as 300 percent of their average monthly household income. This contrasts with on-site sanitation (pit latrines and private septic tanks), where the one-time cost is up to 611 percent of average

Figure 9 | **Comparing sanitation cost burdens in selected informal settlements**

Informal settlement (City)	**OFF-SITE** 55%–300% of monthly household income: Sewer construction and connection cost	**ON-SITE** 166%–611% of monthly household income: Septic tank or pit construction costs	One-time emptying costs
Borella South **(Colombo)**	**300%** monthly income	SEPTIC TANK: **192%** monthly income	**5%** monthly income
Makoko **(Lagos)**	No sewage system exists	VENTILATED PIT LATRINES: **611%** monthly income	**23%** monthly income
San Miguel Km4 **(Cochabamba)**	**140%** monthly income	SEPTIC TANK: **120%** monthly income	**120%** monthly income

Note: On average septic tanks should be emptied every 2 to 5 years, and pit latrines should be emptied every 6 to 12 months. In some cities, in addition to the sewer connection charge there is also a monthly service charge for households.

Source: Authors' analysis, based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

monthly incomes in informal settlements (see Figure 9). If sewers are available, they are likely to be the most affordable option for households to achieve safe and reliable sanitation. However, tenants who rent are dependent on their landlords. Sanitation investments are often associated with higher rent, exacerbating problems of affordability for low-income renters. For homeowners, some form of loan finance or the ability to spread costs over several months can help to ensure access.

The UN Water Supply and Sanitation Collaborative Council suggests that to be affordable, a household's monthly combined expenditures on water and sanitation services should not exceed 5 percent of its income.[95] In our analysis of the 15 cities, we found that in informal settlements in 4 cities, buying minimum recommended quantities of piped water from the water utility (which is usually the least expensive source of water) exceeds 3 percent of income.[96] This is an underestimation of the true cost paid because many households in informal settlements cannot fulfill all their water needs with piped water, and thus spend a larger share of their income on water purchased from vendors and alternative sources.[97] Looking at incomes in the informal settlements, Table 3 suggests that water- and sanitation-related expenditures of 5 percent of monthly household income should be between $2.50 and $25 a month in Africa and Asia, respectively. The cost to empty a septic tank and pit latrine exceeds $25 in almost all cities, which means that households must accommodate a large expense every few years when their pit or tank is overflowing. Our data show that a majority of households choose to "flood out" or not remove fecal sludge, suggesting that on-site sanitation maintenance costs are unaffordable.

5. AFFORDABILITY OF URBAN SANITATION

Urban sanitation is extremely challenging, in part because city governments and policymakers have not paid sufficient attention to cost and affordability from the perspective of the household. If urban sanitation services are unaffordable, households will be unable to safely manage their human waste, imposing neighborhood and citywide health, economic, and environmental risks.

When Sanitation Is Unaffordable, Households Accept More Risk

Sanitation affordability is a significant issue for low-income households. Research suggests that in urban sub-Saharan Africa, low-income households can only afford to pay between $3 and $4 a month for sanitation.[98] Households in higher-income countries may be able to afford more, but in these cases sanitation is more likely to be provided as part of a general charge for other services or to be included in housing costs. For those who live in informal settlements, sanitation is often a distinct good or service that must be purchased; for instance, pay-to-use toilets.

Box 3 | The Reality for Informal Sanitation Workers

In the absence of sewer networks, human waste and fecal sludge is often manually emptied and transported to treatment facilities. In many cities where on-site sanitation lacks regulation and enforcement, pit latrines and septic tanks are emptied by a variety of private and sometimes informal enterprises. In Haitian cities, pit emptiers are known as *bayakou*.[a] In Nairobi, they are known as "froggers."[b] In Dhaka, they are known as "sweepers."[c] These workers all play an important role in managing the city's fecal sludge, yet this type of work receives little compensation and often puts the worker's well-being at risk. For example, *bayakous* in Port-au-Prince haul away fecal sludge one bucket at a time from deep pits without gloves and sometimes without clothing. It is common for these workers to suffer from disease and infections as well as injuries from unknown objects discarded in pits, such as razor blades.[d] The workers work in the middle of the night by candlelight, as this work is deeply stigmatized. Recent cholera epidemics in Haiti have worsened because of this system and the lack of sewage treatment.[e] Across many struggling and emerging cities, pit and septic tank emptiers will collect and dump the untreated fecal sludge in nearby waterways. In the absence of universal access to safe, reliable, and affordable sanitation services, low-cost sanitation workers will remain in demand.

Notes:
a. Estrin, 2018. b. Holland, 2019. c. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.
d. Hersher, 2017a, 2017b. e. Voice of America, 2016.

For those who own their home, sanitation costs are generally a capital investment. In the case of sewer connections, this initial expense is usually followed by an ongoing charge included in a water bill or other sanitation service charge. For pit latrines and septic tanks, costs include constructing the latrine and emptying, transporting, and disposing of fecal sludge. These costs mean that people may empty their pits in unsafe ways (see Box 3).

For renters, access to sanitation may constitute an additional charge. If a toilet is linked to a house or plot, the cost of sanitation may or may not be included in the rent. The costs of emptying a pit may be passed on to a tenant. Tenants in informal settlements or informally subdivided buildings may face limited access to toilets and bathrooms, poor-quality maintenance, and the likelihood that rents will go up if facilities are improved.[99]

Urban households typically use five strategies to keep sanitation costs down. The first is available to all: open defecation and defecation into a bag or waste paper that is then closed or wrapped and thrown away. The second is only available to those with sufficient available land and features a cheap sanitation facility design—for instance, a shallow pit with no slab, enclosed by material draped around four posts. If densities are low enough, they can close the pit and dig another one. The third option, if suitably located land is available, involves households sharing a toilet, including the costs for construction and maintenance. The fourth option, if affordable facilities are available, involves pay-to-use toilets, which allow households to avoid the high initial fixed costs of private facilities. A fifth option, which also depends on available land, is to come together to construct community-managed toilets. These may offer local residents more affordable access—for instance, by issuing monthly household passes—but community organizations need to oversee management and maintenance. These last two options are particularly relevant where plots are too small for individual toilet construction and where there are large numbers of people renting accommodation without sanitation facilities.

Communal or public toilets typically have a charge that appears small but can easily become significant when aggregated across days and family members. Per-use costs for public toilets range from $0.02 to $0.11 in Nairobi and from $0.04 to $0.08 in Kampala, with costs per use of Sanergy toilets at $0.05.[100] A family of six, in which each member uses the toilet four times a day, would incur a daily cost of $1.20 if there is a charge of $0.05 to use the toilet; this will add up to $36 a month.[101] To put this cost into context, lowest-income households may be renting rooms for $15 per month. Such options are not affordable for many who live in informal settlements.

On the other hand, communal or public toilets can dramatically lower the one-time up-front capital cost per household served—from around $300–$450 (as is common in sub-Saharan Africa for a good-quality private toilet) to $22 per household for access to a communal or public toilet.[102] If land is available, toilet blocks are easier to install than household solutions, and they are often more acceptable to local governments.[103] Public and community toilets can also reduce open defecation and provide households with washing facilities.[104] Many cities now have exemplar community toilets and washing blocks that are designed, built, and managed by community organizations (see Box 4).[105]

Shifting Risk and Responsibility Requires Capacity

The 15-city data analysis underscores that if household sanitation service costs are not affordable, households will use unsafe alternatives. The following analysis shows that unregulated or unsubsidized on-site sanitation shifts most of the costs (including financial and time) to households, whereas off-site systems shift the cost to the government or sanitation authority.[106]

Box 4 | Community Sanitation in Mumbai

Mumbai offers a good example of the capacity of community organizations to rethink community sanitation. Supported by Mahila Milan (the federation of women slum dwellers' savings groups), groups of women living in informal settlements or on sidewalks redesigned public toilets so they were managed by the community rather than the local government, providing improved facilities to half a million residents. The Mumbai government paid for the toilets' construction, so the community only pays for operation and maintenance costs. Residents pay for monthly passes that provide access to all household members for less than $2 per month. People passing through the community can access the toilets for a higher fee. This helps cover maintenance costs and can allow the community to hire a full-time toilet manager to work on-site.

Sources: Burra et al., 2003; Patel and SPARC, 2015.

From the perspective of urban households, connections to sewer networks often cost less than the most commonly used on-site sanitation alternatives. This is true if one considers the full cost of building, emptying, transporting, treating, and disposing of fecal sludge as well as the costs of monitoring compliance of on-site sanitation systems. Although there is a technical component to calculating sewer costs, they also reflect political decisions. Other factors that influence costs include existing investments in bulk infrastructure, the cost of extending the network to an under-served settlement, and the cost of sewage treatment plants. There is also the issue of how much it costs to dispose of households' gray water, which some sewer systems provide at no additional charge to the user.

Sewer costs are complicated to calculate. Network costs comprise many components for which the "correct" charges are ambiguous. For example, if the land is already in the public domain, what land costs should be charged? Other components include the cost of capital, which is related to the interest rate charged, the length of time over which loans taken out to finance the network are repaid, and the time over which the capital depreciates. Economic assessment also depends on what is counted under costs and benefits; for example, whether health costs or lost income arising from substandard sanitation are included as costs. As long-term investments are repaid over a long period of time, the cost of a sewerage network partially depends on the discount rate used to compare public net costs or benefits that accrue in different time periods. Governments use discount rates to account for "time preference," or the value of having money today rather than tomorrow. The discount rate will make a significant difference to net costs.[107]

A detailed study of the financial requirements for urban sanitation in India from 2011 through 2031 illuminates the costing challenge.[108] The study analyzed the financial resources required to provide universal sanitation access for all households within cities, as well as for the floating urban populations, to provide safe collection, conveyance, and treatment of human waste. It is estimated that new and replacement investment costs ₹5,200 billion ($111 billion), of which ₹1,580 billion ($34 billion) is assumed to be paid by households. Operation and maintenance are estimated to cost ₹2,647 billion ($57 billion) from 2012 to 2031.[109] The bulk of this operation and maintenance expenditure, 94 percent, is attributed to the functioning of the wastewater collection network and treatment plants.[110]

The assessment of economic costs depends on the length of time over which the investment cost is spread. It is reasonable to use relatively short periods for household investments, but state investments are likely to stretch over long periods of time. For example, the India study uses 20–30 years for the sewerage networks and treatment infrastructure.[111] Although these periods align with what is recommended by the Central Public Health and Environmental Engineering Organization, it is likely that infrastructure investments will last longer than this.[112] Spreading the costs over a longer time period—such as 50 or 100 years—will further reduce them, and the extent of the reduction also depends on the discount rate used.

Returning to the assessment of long-term plans to reach universal sanitation in urban India, even with this scale of investment, the plan includes pit latrines, which, it suggests, will continue to be significant even in 2031, with 16 million households, or 10 percent of all Indian households, using them.[113] It also predicts that in 2031, 37 million households (22 percent) will be dependent upon septic tanks, and 63 percent will have access to sewers.[114] About 30 percent of wastewater will not be treated due to the continuing presence of on-site sanitation, which will in turn have considerable health risks.[115]

Table 5, compiled from data reported in the study, shows the costs incurred for both household and city provision for three

Table 5 | **Comparative Sanitation Capital Investment Costs in Urban India**

COSTS OF DIFFERENT SANITATION TYPES	HOUSEHOLD COSTS (US$)	CITYWIDE ASSETS COSTS (US$)	TOTAL COSTS (US$)
Pit latrine with septage costs	298	78	376
Facility with septic tank and septage costs	477	78	555
Facility with sewer connection and treatment	234	428	662

Notes: Cost figures are from 2011. For figures in U.S. dollars, the Organisation for Economic Co-operation and Development exchange rate for 2011 of ₹46.67 to US$1 was used for calculations.

Source: Weitz et al., 2016: 21–22.

sanitation options. It shows that the sanitation facility with full sewage treatment is the most expensive overall but has the lowest costs for the household.

Sewer-connected household toilets are an affordable option from the household's perspective, but they require significant public investment. Nonsewered sanitation options can also be more affordable if financed publicly, similar to sewer networks. Although pit latrines can be constructed relatively inexpensively, this is less the case if they are built to be emptied and reused, and even less so if the household has to pay for the entire sanitation service chain. This also does not take into consideration situations where pit latrine construction is not possible.

Septic tanks are significantly more expensive than household sewer connections—in the case of urban India, almost twice the cost. Such calculations, however, require many assumptions. For example, the 15-city study shows that in Bengaluru, the cost to construct a facility connected to a private septic tank is similar to the cost to construct a facility connected to sewers given the charges made by the utility; however, the cost to empty the septic tank was more than three times the cost of initiating a household sewer connection. Comparing estimated costs of different sanitation options is difficult over large countries and long time periods because, among other things, it involves making assumptions that are technical (design of system), political (how infrastructure is valued over time), and fiscal (what tariff rates cities can charge to users).

6. URBAN SANITATION ACTION AREAS

Most struggling and emerging cities will need to consider the full range of off-site and on-site approaches to find the optimal combination that suits their specific context.[116] Regardless of the combination of sanitation approaches ultimately used, there is a role for city-level authorities in governance, finance, planning, and regulation. We suggest that urban change agents concentrate their resources and efforts in the following four action areas (see Figure 10):

- ***Cities need to extend the sewer network to household, communal, and public toilets.*** Sewers and simplified sewers are convenient, safe, sanitary, and work well in densely populated urban environments and where multistory buildings are common. Sewers reduce the responsibility for and cost of sanitation services from the perspectives of individuals and households. However, building and extending sewer systems require large capital investments and daily supplies of water to work properly.

- ***In the absence of sewer systems, cities need to support and regulate on-site sanitation options such as septic tanks and pit latrines.*** Presently, quality and safely managed on-site sanitation is unaffordable for many low-income households, so unsafe practices persist. Cities need to work with households and communities to make the entire on-site sanitation service chain safe, reliable, and affordable. On-site sanitation also requires strong public capacity to regulate and enforce safe practices.

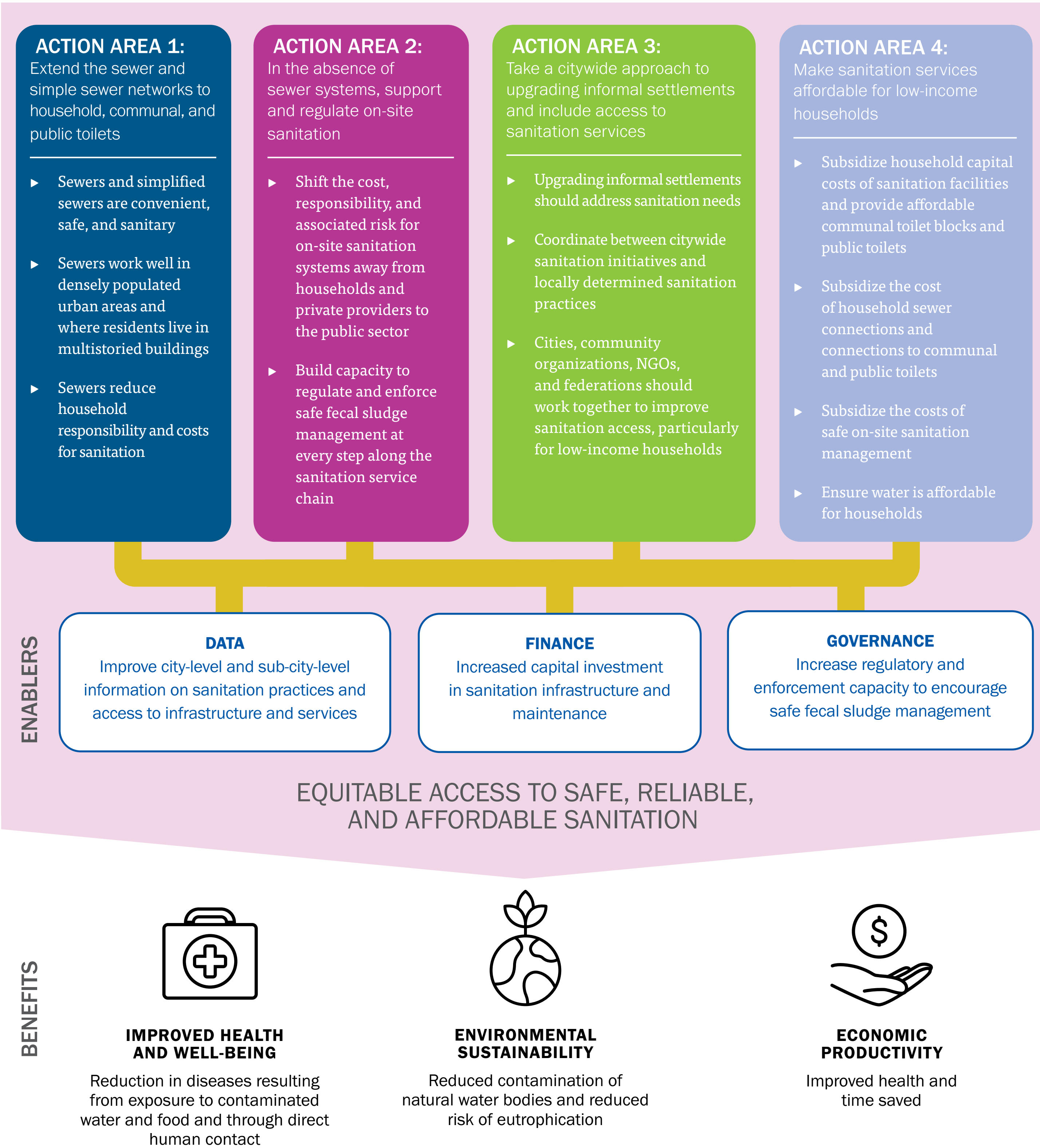
- ***Cities should take a citywide approach to upgrading informal settlements that addresses the need for urban sanitation services.*** When cities upgrade informal settlements, they should coordinate between citywide sanitation initiatives and locally determined sanitation practices to ensure safe management of sewage and fecal sludge. Cities need to work with community organizations, NGOs, and federations to improve and extend sanitation services to low-income groups.[117] Cities should collaborate with these organizations to address access to sanitation because they are in a position to respond to users' needs and priorities while working within local constraints, particularly affordability.

- ***Cities need to make a variety of sanitation services more affordable for low-income households***. This includes subsidizing the capital costs of sanitation from the perspective of the household (i.e., bathroom construction, the cost of toilets, and septic tank construction). It also includes building communal toilet blocks and public toilets. Making sanitation affordable means subsidizing the cost of sewer connections to household, communal, and public toilets as well as subsidizing the costs of safe on-site sanitation management, including emptying, transporting, treatment, and disposal.

Off-Site Sanitation: A Long-Term Investment

Well-functioning sewer systems are convenient, safe, sanitary, and, when life cycle costs are considered, not as expensive as they might seem based on the high initial capital investment, especially when public health and environmental benefits are considered. However, as previously discussed, sewers presuppose the presence of sufficient water and public sector capacities.

Figure 10 | **Priority action areas for cities and urban change agents to improve equitable sanitation access**



Note: NGOs refers to "nongovernmental organizations."

Source: Authors' analysis.

Citywide sewers

There is a vociferous environmental lobby that argues against using sewers to improve sanitation, suggesting that they require a lot of water and power and fail to return nutrients to the soil.[118] But there are valid answers to most of these criticisms—including reducing the amount of water needed (by reusing gray water) and invoking a range of methods to treat or reuse sewage and wastewater, including in food production.[119] Sewer systems are often said to be too expensive for many cities in the global South, but economies of scale, the time period over which these costs are spread, and high population densities have the potential to reduce costs. Sewers function for a long time, but their entire life cycle costs are often not considered. For instance, many cities have at the core of their sewer system a network that is over 100 years old. Once installed, sewer systems make it easier to maintain adequate safety standards and prevent leakage along the sanitation service chain.

In high-income nations and in many middle-income ones, governments play the central role in funding, installing, managing, and expanding the sewer systems and treatment plants that serve almost all urban residents. As illustrated by the 15-city study, there are also examples of informal settlements where almost all of the population is connected to sewers.[120] In providing for both sewers and treatment plants, there is scope to contract out tasks to private enterprises. However, the expansion and extension of sewers are typically planned, regulated, and managed by city governments or by utilities that work with them. During the 1980s and 1990s, many international agencies promoted the privatization of water and sanitation in cities.[121] Although this policy shift was not successful,[122] private sector involvement has continued in the sector: however, it usually takes the form of contracts for specific projects or management tasks.[123]

Some of the cost data from the 15 cities and informal settlements challenge the conventional wisdom that sewers are expensive, out-of-reach solutions for cities in the global South. Based on the data we gathered, sewer connections in many of the cities and some informal settlements are the *most* affordable long-term approach to sanitation. If water is available and affordable, providing sewers may be less expensive per household served than good-quality on-site sanitation (such as high-quality pit latrines or septic tanks), especially when emptying, transportation, and treatment costs are included. The cost of supervision and compliance with regulatory standards are also likely to be lower for sewers compared to on-site facilities.

Several Latin American countries have made noteworthy strides in expanding sewers and wastewater treatment in recent decades. For example, in Montevideo, Uruguay, the percentage of homes connected to sewers rose from 74 percent in 1985 to 92 percent in 2002 as part of the expansion of the public system.[124] Progress has also been made in Porto Alegre, Brazil. Consider that in 1988, sewerage networks there extended just 768 kilometers (km) and only 2 percent of wastewater was treated; by 2000, however, the networks stretched 1,399 km and 27 percent of wastewater was being treated.[125] In Salvador, Brazil, a program jointly financed by the Brazilian government and international funders expanded the citywide sanitation system by "laying more than 2,000 km of sewer pipes, constructing 86 pumping stations, and connecting more than 300,000 households to the sewer network over a period of eight years (1996–2004)."[126] Rosario, Argentina, implemented a large-scale upgrading program for those living in informal settlements that included the extension of sewers.[127]

Progress in expanding and extending citywide sewer systems in Latin America was in part driven by political changes in the 1980s and 1990s, including the shift to elected mayors and city governments, having more open and transparent city governments, and adopting participatory budgeting.[128] In some nations, city governments saw substantial increases in their funding base as the result of decentralization reforms.[129] There was also a new generation of mayors elected as well as professionals (engineers, academics, medical doctors, and architects) who were committed to expanding and extending core urban services, including water and sanitation.[130]

Much of the global South's urban fabric comprises informal settlements, which makes sewer provision more difficult.[131] Informality makes sewer provision more difficult because plots are irregular and often houses are only accessible by small footpaths. Installing sewers is easier and less expensive where settlements are laid out on a grid and houses are served by access roads that can be used to bring in building materials and equipment. Cities can actively manage urban expansion by laying the foundational infrastructure for sewers and other basic services (e.g., streets and piped water systems) before informal development occurs.[132] It is much easier and less expensive to install piped water and sewers on new and undeveloped sites. Where settlements are informally built, some areas may need to be reblocked to add space to install water pipes and sewers. There are many examples in global South cities where residents of informal settlements participate in upgrading informal settlements, and these efforts include the provision of sanitation services.[133]

Simplified sewers

Simplified sewers have a number of advantages. Instead of connecting to every plot, simplified sewers provide a single connection point to each city block, and thus the network is shorter than that of a conventional city sewer system.[134] Other advantages of simplified sewers is that they can be built and repaired using locally available materials, installed in irregular settlements, and extended as the community grows, making them particularly appropriate for rapidly growing, dense urban areas.[135]

The planning, financing, implementation, and management of simplified sewers usually requires community participation, and thus clearly delineated responsibilities between the sanitation authority and the community.[136] Although community participation can facilitate installation, some irregular settlements may still need to be reblocked.

Simplified sewers (or more commonly referred to as condominial sewers in Brazil) reach half a million people in Brasília and 1 million in Salvador.[137] In fact, Brazil's scaling up of its condominial system has been driven by the need to keep sanitation costs down. Funding for simplified sewers has been provided by the Federal Development Bank and the Inter-American Development Bank.[138] In La Paz and El Alto, Bolivia, a 2009 financial study showed that households saved 40–50 percent by installing condominial sewers with community labor, as compared to municipal sewers.[139]

A challenge of simplified sewers, similar to conventional sewers, is that they require residents to have access to reliable, affordable, and adequate water supplies.[140] According to WHO, individuals need at least 50 liters of water per day for their total consumption—so it should be assumed that ultimately, in urban areas, households will need access to at least this amount, and it is much more common for individuals to use between 100 and 150 liters of water per day.[141]

Another challenge for simplified sewers is that blockages and repairs are often residents' responsibility. One reported drawback of simplified sewers is that residents may be unaware of a blockage until it becomes serious and expensive to repair.[142] Ideally, the public utility or government sanitation service provider works with residents to select an appropriate design for the simplified sewer and commits to providing supportive actions that range from sanitary education to direct construction and maintenance.[143] The operating costs of simplified sewers are 50–80 percent less than conventional sewers and can be less expensive than some on-site sanitation options.[144]

Karachi, Pakistan, is another place where simplified sewage has increased people's access to sanitation services. A local NGO, the Orangi Pilot Project (OPP), was started in 1981 to assist in community-government partnerships in one of Karachi's largest informal settlements. With support from the OPP-Research and Training Institute (OPP-RTI), its model of simplified sewers spread to many other communities in Karachi as well as to other cities. Through the OPP-RTI's various sanitation programs, 107,090 households in Orangi and 46,821 households in 284 other locations in Pakistan have built and financed their own underground sanitation systems at the neighborhood level while the state has supported the building of trunk sewers and sewage disposal points.[145] The work also includes the OPP-RTI's support to local government agencies for converting open streams or drains into trunk sewers and upgrading existing drains.[146]

Where state investment was limited, the OPP-RTI supported all households in a lane to cover the cost of installing sewers to which they could connect their toilets.[147] This created a sense of

Simplified sewers have a number of advantages. Instead of connecting to every plot, simplified sewers provide a single connection point to each city block, and thus the network is shorter than that of a conventional city sewer system.

community ownership over the system, which was important for its construction and maintenance. The OPP-RTI provided the technical support for installing the sewers and brought down costs through introducing simplified designs, negotiating lower prices with local skilled labor, and by avoiding paying bribes. The cost to put the sanitation facility in the house and connect it was between $15 and $50 per household over the last decade.[148] No subsidy was needed as household contributions covered these costs, although the technical advice was provided free of charge. The per-household cost varied considerably depending on the sewer's length, between $1.03 and $3.10, or an average of $2.06 for each household.[149]

Based on a new collaborative model, the lane associations took care of the lane sewers' internal components, and state agencies were responsible for the secondary and main sewers, drains, and waste treatment plants. Two factors unique to this case help explain the feasibility of this approach. First, residents owned their own homes and could commence construction without needing to obtain permission from a landlord. Second, building costs were low, and individual plots and dwellings were large enough to install toilets without requiring additional construction.[150]

Designing effective community-based sanitation is more complex when land tenure is not clear, where there are significant numbers of renters (some of whom worry that upgrading will increase rents), where other services are lacking (particularly water and drainage), and where there are challenging geological and topographical conditions.[151] More effective community-led sanitation models are likely to require technical and professional expertise as well as the organizing capacities of community leaders. To work at scale, community organizations need support from relevant government agencies to have the financial and technical capacity to maintain the system. For example, researchers from Pakistan reported that the sewer lanes were no longer effective in Ghaziabad, the informal settlement, because of poor maintenance.[152] Experience has shown that some form of collaboration is essential both to ensure local management and to reduce costs. Collaboration requires building political will and incorporating coproduction modalities within local government and the utility.

On-Site Sanitation: A Short- and Medium-Term Approach

In some urban contexts, sewer systems are currently beyond the capacity of city governments and local utilities. Some cities have inadequate financing to cover large up-front capital construction costs, and other urban areas have local water and energy constraints that do not support sewers. Most international aid agencies and development banks have given a low priority to loaning money for installing or extending sewers. In the absence of a well-functioning sewer system that connects all households to a treatment plant, on-site sanitation management systems are required. Most alternatives to sewers involve septic tanks, pits, or containers that need to be emptied regularly, with adequate supervision at all points along the sanitation service chain to ensure public safety (see Box 5).

Private and communal septic tanks

If septic tanks are properly constructed and well maintained, they can safely treat human waste and relatively large amounts of gray water. It should be noted that tanks with an open bottom are sometimes mistakenly identified as septic tanks.[153] Septic tanks also have the added advantage of allowing future connection to a sewer system. Besides regular emptying, septic tanks require little maintenance and can serve residential complexes and other buildings, which can reduce their per-household costs. However, there is evidence that many septic tanks in the global South are rarely emptied and are too full to perform primary treatment.[154]

To facilitate desludging, septic tanks should be located so vacuum trucks can access them; however, dense settlements often lack the space and road network for vacuum trucks. In some areas where individual and communal septic tanks are common, an emergence of small-scale and alternative private providers will perform desludging services.[155] However, in many locations these private providers are unregulated. There is tension between public safety regulations and providers' need to be flexible and inexpensive so low-income households can afford their services. With private and communal septic tanks (as well as with pit latrines), the government can play a role in establishing and enforcing standards regarding septic tank design, regular emptying, and inspection to protect public health and local water supplies.

Communal septic tanks, on the other hand, are often constructed using capital investment costs covered by development agencies, or they are shared by community organizations or resident associations. When costs are shared among many households and the system is communally managed, these tanks become much more affordable. In Karachi, for example, communal septic tanks are less expensive per household than private ones because communities can share land, permit, and labor costs.[156] However, maintenance and desludging requirements depend on a variety of factors that can increase operational costs and pose environmental and health risks if not executed to a sufficient standard.

Septic tanks are common in Indonesian cities. Since 2000, the Indonesian National Development Planning Agency has constructed over 1,700 decentralized wastewater treatment systems in urban areas.[157] Many of these systems use simplified sewers that connect to communal septic tanks.[158] For example, in Medan, Indonesia's third most populous city, various NGOs and the U.S. Agency for International Development helped train local sludge collection operators to use small desludging machines to reach households located along narrow lanes. In this model, the municipal sanitation department is supposed to support the safe emptying, treating, and disposing of fecal sludge; however, this is rarely achieved.[159]

Fecal sludge management remains a challenge in Indonesian cities. The Indonesian Standard Code for Planning Septic Tanks, although comprehensive in its design criteria, is not well enforced by local governments, and there is a lack of local capacity to fulfill the standards set by the code.[160] Medan's urban population relies almost entirely on septic tanks; more than 400,000 of them serve the city's population.[161] However, there are no regulations that pertain to emptying and desludging these tanks.[162] The municipal sanitation department only operates a few emptying trucks, and many private operators help to address this service gap.[163] Because disposal regulations are rarely enforced, most fecal sludge is illegally dumped into waterways.[164] For septic tanks to operate effectively, there must be a strong legal, institutional, and financing framework for emptying, transportation, treatment, and disposal.

The city of Haiphong, Vietnam, shows how a public utility can partner with local enterprises to support safe fecal sludge management.[165] The Sewer and Drainage Company, a public utility enterprise, is responsible for Haiphong's septage collection; it uses vacuum tankers and small vacuum tugs for areas that are difficult to access with regular-sized trucks. The smaller vacuum tugs are used with intermediate storage tanks mounted on a hook-lift truck, developed by the utility in collaboration with a local manufacturer.[166] The combination of large and small equipment has proved effective, with the potential to serve almost 100 percent of the houses.[167] However, there is little regulation of fecal sludge collection, treatment, and disposal in Vietnam, and in 2011 one study reported that a quarter of households with septic tanks in Haiphong have never emptied their tanks.[168]

In the Philippines, the National Sewerage and Septage Management Program was started in 2004 to help all local governments develop fecal sludge management systems and for the 17 highly urbanized cities to develop sewer systems.[169] This program was designed to provide government support and incentives for local implementers to build and operate wastewater treatment systems.[170] In 2017, it was reported that more than $1 million set aside for this subsidy program was still unused.[171] Many cities faced a lack of political will and conflicts between local government and water districts in implementing the program.[172]

In contrast, a report on living without sewers in Latin America highlights how the demand for septic tank or pit latrine emptying is being served by private enterprises without government involvement.[173] In the peri-urban areas of Santa Cruz, Bolivia; Guatemala City, Guatemala; Tegucigalpa, Honduras; and Managua, Nicaragua, much of the population relies upon on-site sanitation systems such as septic tanks and pit latrines.[174] There has been no systematic effort to develop services to maintain the tanks or to remove fecal sludge. As a result, waste tends to exceed the capacity of on-site sanitary facilities and spills into roads, ditches, gullies, and ravines near the collection point. In all four cities, private enterprises have developed in response to the demand for such services.[175] However, the absence of government involvement and regulation of this sector raises serious questions about public safety.

Pit latrines

The advantage of pit latrines is that they can be built and repaired with locally available materials and they require relatively simple and inexpensive technology. However, the case of Dar es Salaam highlights some of the challenges of pit latrine use in densely populated urban areas. In Dar es Salaam, 80 percent of that city's sanitation facilities are pit latrines yet only 23 percent of these are fully lined.[176] Many parts of the city, especially in dense and unplanned areas, are regularly exposed to overfilled pits and illegal disposal near households. The lack of roads and inaccessibility of many plots limits properties' access to safe emptying services. When pits are emptied, latrine owners incur additional costs, as the only way to empty the pit is to modify the superstructure or floors. One study found that when residents had access to safe emptying services, households were more willing to frequently empty and upgrade the pit latrine's structure and lining.[177] In another article by the same authors, it was suggested that public investment to create widespread access to hygienic emptying services could stimulate greater private investment in and access to safe and sustainable sanitation.[178]

Numerous technologies have sought to improve the handling of fecal sludge from pit latrines and septic tanks. These include a smaller version of the vacuum tanker, such as Vacutug trucks, that can get down roads too narrow for regular trucks. There is also a range of hand-operated systems that can be used in households that are inaccessible by vacuum tanker. These include gulpers, nibblers, gobblers, rammers, and MAPETs (manual pit emptying technology).[179] The hope is that these technologies can reduce the cost of pit and septic tank emptying to the point where low-income households can afford such services, while also providing opportunities for private entrepreneurs. Doing so means being able to compete with inexpensive but unsafe and illegal practices and having strong systems of public regulation as well as enforcement.

Box 5 | Challenges of On-Site Sanitation in Urban Areas

The data collected in 15 cities in the global South highlights some common challenges of on-site sanitation.

Mzuzu, Malawi, lacks a citywide sewer system, and as a result, over 90 percent of the city's residents rely upon on-site sanitation. A major challenge is the city's high water table. High groundwater levels increase the risk of seepage and flooding from household septic tanks. Pit latrines, which are more commonly found in informal settlements, are often built with less expensive materials or no lining and can become vulnerable to flooding, overflowing, and collapsing, especially during rainy seasons. The 15-city study also found that in the selected informal settlement, a majority of unlined pit latrines were less than the recommended 30 meters away from shallow wells and boreholes. Whereas some pit latrines are left to flood out, the contents of others are dumped in nearby waterways or in rural areas or are buried.

In **Lagos, Nigeria,** a majority of households rely upon on-site sanitation systems and groundwater to meet their household needs. As a result, groundwater quality and contamination are a concern when fecal sludge is not safely managed. Prior to 2010, almost all fecal sludge was directly discharged into water channels and water bodies. In 2012, the Lagos Lagoon was closed as a result of excessive sludge discharge. With over 70 percent of the city relying on groundwater from boreholes and tube wells, large segments of the population were at risk of consuming contaminated water. The Lagos State Water Regulatory Commission was created after 2012 in part to regulate fecal sludge dumping, and in 2017 the city passed an environmental law prohibiting the use of pit and bucket latrines. Although this law is not fully implemented, it is an initial step towards regulating on-site sanitation and addressing safety concerns.

In **Dhaka, Bangladesh,** 80 percent of households rely on groundwater and use septic tanks. Instead of being periodically emptied, most septic tanks are connected to nearby drainage networks that connect to drainage channels. This often produces wastewater volumes over the capacity of the city's treatment plants. As a result, the city's plant only treats about 3 percent of Dhaka's sewage, and the remainder is disposed of in water channels. Recently, Vacutug trucks, run by a fecal sludge collector introduced by the city utility and the United Nations Children's Fund, have helped address the sanitation service gap, reducing the amount of septage in city drainage channels. A private company operates the rented Vacutug trucks to safely empty and transport sludge to treatment stations for $15 (Tk1,200) per 2,000 liters of fecal sludge. The city utility also mandated that the service is prioritized for slum areas with a 20 percent discount, subsidized by the government. Demand for the service continues to increase, and this program highlights how cities can facilitate innovative solutions for fecal sludge management.

Source: WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

When it is either impossible or unaffordable to safely empty a pit latrine, residents might use "flooding out" or "vomiting," a technique that involves "intentionally releasing sludge into the neighborhood by unplugging a drain pipe installed in an elevated or exposed portion of the pit often timed with heavy rains."[180] Over 40 percent of residents in Dar es Salaam reported that flooding out is routinely practiced; it was the third most common emptying method after vacuum tanker and pit diversion.[181] In our 15-city study, flooding out was also reported as a common emptying method in Mzuzu and Nairobi.[182] The practice of flooding out pit latrines underscores the broader public health risks of leaving individuals and households responsible for managing their own human waste in densely populated urban areas.[183]

Pit latrines have the potential to serve as a low-cost, safely managed sanitation system in lower density and peri-urban areas if regular emptying and improved design are mandated, operationalized, and enforced by the municipality. As part of the WRR, an in-depth case study of urban transformation in Kampala found that the city government has successfully partnered with small businesses, community groups, and the national water and sanitation utility to improve fecal sludge collection from pit latrines.[184] Between 2003 and 2015, Uganda's national utility increased its fecal sludge treatment rate by thirtyfold without a large increase in sewerage coverage.[185] This was in large part due to the Kampala Capital City Authority's (KCCA) facilitation of nontraditional sanitation technologies such as the gulper, a portable vacuum pump that empties latrines and transports fecal sludge on smaller three-wheeled vehicles to larger tanks.[186]

Container-based sanitation

Container-based sanitation (CBS) has several advantages. New variants of CBS provide good-quality toilets and significantly reduce the risk of exposure to pathogens from fecal waste, both for users and service providers. It is relatively low risk for service providers because the excreta-filled containers are safely sealed before they are collected and transported to designated treatment and disposal sites. CBS is relatively compact, so it works for small houses, and households can choose where to locate it in the home. Because there is no underground infrastructure, it is easier to keep indoors and can be used in multistory buildings, and using a small amount of additive can eliminate odors and insect infestations.[187]

CBS has the potential to overcome some difficulties usually experienced by renters because they can install and use it with no cost to landlords, and it requires little modification to the residence.[188] Container-based toilets are also appropriate for informal settlements where the municipal authorities either cannot or will not make infrastructure investments.[189] However, a portable one-seat toilet requires some land or space within the dwelling. Evidence suggests that CBS service is relatively costly—at least at the scale at which it currently operates—and hence presents a financial challenge for low-income households (if not subsidized).[190]

Most CBS initiatives are implemented by NGOs or community-based organizations. CBS has become a popular option in densely populated areas of urban Haiti, where large two-chamber toilets are not practical.[191] The NGO, Sustainable Organic Integrated Livelihoods (SOIL), provides a urine-diverting dry toilet for a monthly rental fee and arranges for containers to be collected and transported to a compost facility on a weekly basis.

The use and costs of this system were evaluated in Shada, an informal settlement in Cap-Haïtien, Haiti.[192] A baseline survey in Shada, taken prior to the introduction of CBS, found that around half of all households used free public toilets during the day, but only a third used them at night, when they reported higher use of flying toilets and open defecation.[193] After three months of CBS, 87 percent were very or generally satisfied compared to those without CBS, who reported only 35 percent satisfaction.[194] The study found that bringing toilets into the home did not increase fecal contamination of water and virtually eliminated reports of open defecation or flying toilets.[195]

SOIL reports that in 2018 it scaled to over 1,000 households.[196] Recent analysis shows that if households were responsible for the full monthly cost of the service, it would cost approximately $14.92.[197] However, revenue from household fees and compost sales currently cover about 30 percent of these costs, and the remaining costs are met with donations. As such, SOIL maintains a monthly household service fee of $3.[198] Annual costs to households are $36, which is comparable to the cost of using an informal provider to empty a pit latrine and is less expensive than Haiti's formal providers.[199] However, even with subsidies, many low-income households cannot afford this service, highlighting the need for a long-term public financing solution.[200] Treatment also remains a challenge with this model, requiring long processing times and physical space.

Another example of CBS comes from the work of the Clean Team, a social enterprise in the densely populated city of Kumasi, Ghana, that provides freestanding, urine-diverting chemical toilets to households, with regular emptying services. Feces are collected in sealed and removable containers and are then transported to a treatment plant.[201] By 2016, the Clean Team was serving over 500 households.[202] On average, households pay $11.02 per month, whereas a household of four in the same location spends up to $18 per month on pay-per-use public toilets.[203] The majority of Clean Team households were previously public toilet users but switched because CBS is a more convenient and less expensive alternative. However, CBS is still unaffordable for the lowest-income households.[204]

The economic viability of CBS depends on the scale of operation in the short term. In the long term, it depends on the relative cost of labor and capital. As labor costs increase relative to the cost of capital, alternative more capital-intensive sanitation solutions such as sewers start to become more financially attractive. In peri-urban areas, there are other emerging on-site innovations such as composting toilets, but these are not appropriate to conditions in dense urban areas.[205] The feasibility of these typically depends on the cost of land, the affordability and footprint of particular models, and the availability of markets for biosolids.

The importance of on-site sanitation can be seen in contexts where there are neither the conditions nor the public sector capacity to support sewers or a simplified sewer system.[206] However, quality on-site sanitation, especially when considering the cost of the entire sanitation service chain, is often too expensive for low-income households. In these cases, the public sector can provide finance and subsidies and work with communities and households to provide services to ensure safe containment, collection, treatment, and disposal or reuse of human waste. There may also be a role for the private sector in the on-site sanitation service chain (see Box 6), but because of the inherent public health risks, public sector regulation and enforcement will always be needed. Table 6 summarizes the accessibility benefits, weaknesses, and challenges to scalability for each sanitation option.

Box 6 | Reinventing the Toilet without a Water and Sewer Connection

In 2018 the Bill & Melinda Gates Foundation joined with inventors, representatives from international development banks, corporations, and sanitation utilities and governments to host the first Reinvent the Toilet Expo in Beijing, China, where new sanitation technologies were on display. The expo builds on several years of financial support to create a new toilet that

- removes germs from human waste and recovers energy, clean water, and nutrients;
- operates without being connected to a piped water system, sewer, or electrical grid;
- costs less than $.05 per use per day; and
- creates sustainable and financially profitable sanitation services in poor, urban settings.

One example of this new generation of toilet is the nano membrane toilet, which is designed to be used by a single household and does not require urine and feces to be separated. The toilet uses membranes to move and treat urine so it can be used by the household for washing and irrigation. Feces and residual solids are moved by mechanical screw into a combustor that converts them into ash and energy. The energy powers the membrane and has the potential to produce extra energy for charging low-voltage electronic items and appliances. The prototype has been tested in peri-urban areas in the eThekwini municipality in South Africa. One of the most significant challenges for struggling and emerging cities is making these toilets affordable for low-income households.

Sources: Wee, 2018; Hennigs et al., 2019; Bill & Melinda Gates Foundation, n.d.; Cranfield University and Bill & Melinda Gates Foundation, n.d.

Table 6 | **Sanitation Options for Cities**

	COST BURDEN	CAP-ITAL	ON-GOING	PUBLIC HEALTH AND SAFETY RISK	WATER DEMANDS	ACCESSIBILITY ADVANTAGES	ACCESSIBILITY CHALLENGES	POTENTIAL FOR CITY SCALABILITY
CITYWIDE SEWERS	Household	$	$	Lowest	High	Reliable Does not require much space in the house	Dependent on daily water supply Potentially inaccessible to those without land tenure and to renters Municipality has to provide service	High capital investment costs Depends on the availability of energy for the sewage treatment plant City or utility must have capacity for system maintenance and expansion Requires functioning sewage treatment plant
	Community	$	$					
	Public Authority	$$$	$$					
SIMPLIFIED SEWERS	Household	$	$	Low	Medium	Flexible design Can be installed in existing irregular and informal settlements Easy to extend as household demand increases Does not require much space in the house Can be built using local materials	When installed in irregular and informal settlements may require some reblocking Requires technical assistance	Depends on community participation In the absence of local treatment capacity, requires connection to nearby municipal sewer infrastructure and a local treatment plant Needs to connect to functioning sewage treatment plant
	Community	$$	$					
	Public authority	$$	$					
COMMUNAL SEPTIC TANK	Household	$$	$	Medium	Medium	Can serve multiple households in dense urban settings Can be built by the community Can connect to a sewer system Risk of contamination	Requires regular desludging and maintenance	Depends on community participation If not connected to sewers, requires transporting fecal sludge to a treatment plant
	Community	$$–$$$	$					
	Public authority	$	$$					
PRIVATE SEPTIC TANK	Household	$$$	$$	Private, high Communal, medium	Medium	Can serve single households Difficult to fit into small plots or densely populated areas Risk of contamination	Needs regular desludging In most places, responsibility for desludging and maintenance falls on households and building owners	Government needs to regulate and enforce safe construction, desludging, transport, treatment, and disposal If not connected to sewers, requires transporting fecal sludge to a treatment plant
	Community	NA	NA					
	Public authority	$	$$					

Table 6 | **Sanitation Options for Cities (continued)**

	COST BURDEN	CAPITAL	ONGOING	PUBLIC HEALTH AND SAFETY RISK	WATER DEMANDS	ACCESSIBILITY ADVANTAGES	ACCESSIBILITY CHALLENGES	POTENTIAL FOR CITY SCALABILITY
PIT LATRINES	Household	$–$$	$$	High	Low	Low technological inputs Can work well in urban areas with low population density	Plot must have adequate space Does not work for multi-story buildings High risk of contamination if not properly lined and emptied Increased risks in areas prone to flooding Inappropriate where water tables are high Risk of groundwater contamination	Requires strong city management capacity for regulating construction, desludging, transport, treatment, and disposal Requires government capacity to enforce regulations Requires the availability of fecal sludge treatment facilities
	Community	NA	NA					
	Public authority	$	$$					
CONTAINER-BASED SANITATION	Household	$–$$	$	Medium	None	Easy to empty Works well in areas with high population density and tenants Portable and works in multistory buildings Requires little space and adjustment in the household Well suited for emergency contexts	Currently not widely available Lack of social and cultural acceptance	Difficult to achieve long-term financial viability because of the challenge to find markets for waste Currently all examples managed by NGOs
	NGO	$$$	$$					
	Public authority	NA	NA					

Note: NGO refers to "nongovernmental organization."

Sources: Melo, 2005; Ndezi and Schermbrucker, 2014; Banana and the Zimbabwe Homeless People's Federation, 2015; CORC, 2015; Gallo and the Malawi Homeless People's Federation, 2015; Mitlin and Schermbrucker, 2015; Ndezi, 2015; Nyamweru et al., 2015; Hoffman, 2016.

Upgrading Informal Settlements to Address Urban Sanitation

Upgrading schemes may be among the most important government-supported initiatives to improve urban sanitation because they usually include better provision for household water as well as sanitation infrastructure.[207] Informal settlement upgrading may include extending sewers, storm drains, and surface drains to the settlement, connecting them into city systems. However, many cities and small urban centers in sub-Saharan Africa and Asia only have sewers that serve a small portion of the urban area, or they lack sewers entirely. In these contexts upgrading schemes can support more locally determined approaches to sanitation, like building and providing access to communal septic tanks.

Government-led upgrading ranges from rudimentary improvements (investment in drains and provision of public taps) to comprehensive improvements that include provision for piped water and sanitation connections for all plots (or dwellings), storm drains, and solid waste collection. Some upgrading is community driven, and in other cases, communities and governments work together, such as the Baan Mankong program in Thailand, where hundreds of community organizations led the work on the ground with financial support from the national government. These efforts secure land tenure and improve access to core urban services, such as water and sanitation, and work to link them to formal sanitation systems.[208]

There are also many examples of community-driven upgrading undertaken by the slum/shack dweller federations that improve the provision of urban sanitation services. For example, in response to the lack of data about sanitation in informal settlements, Slum/Shack Dwellers International (SDI) leads a coordinated community-led mapping and profiling effort that is part of the Know Your City campaign.[209] This work has been undertaken by over 30 national slum/shack dweller federations in thousands of informal settlements in close to 500 cities.[210] The data and maps provide the basis for initiating upgrading schemes and fill an important data gap about sanitation. This systematic effort includes collecting information on access to sanitation services, the cost of sanitation, infrastructure availability and use, and sanitation practices. There are also detailed questions about provision for water, drainage, solid waste collection, and electricity. Residents of the informal settlement own the data, and this has proved valuable in developing working relationships with local governments.

Another example of innovative practice is the support for community action by the Asian Coalition for Community Action (ACCA). ACCA catalyzed community-driven upgrading in 19 countries in Asia.[211] It has supported upwards of 1,000 small community-upgrading projects and more than 100 larger housing initiatives.[212] The most popular interventions have been improvements in water, sanitation, drainage, solid waste management, electricity and street lights, and community centers. This program underscores the need for cities to transcend sectoral approaches and even settlement approaches. Cities need to think about citywide upgrading and how to provide integrated packages of core urban services, including sanitation services and infrastructure.

People need sanitation services, which are often unaffordable, and household expenditures on sanitation are typically given lower priority compared to other essential needs. This results in open defecation and the improper disposal of untreated fecal matter (in a variety of forms).

7. ENABLING EQUITABLE ACCESS TO URBAN SANITATION

The 15-city data we compiled demonstrate that in many cities of the global South, only a fraction of human waste is safely treated and disposed of. Although a range of off-site and on-site action areas have been described, the analysis in this paper raises the question: Why is there so little achievement in providing sanitation services in cities in the global South? Part of the answer lies in the key enabling conditions for cities, including having the governance and regulatory capacity to develop and manage citywide sanitation systems and adequate financial flows to meet capital and system maintenance expenditures.

Governance and Regulation

The challenge of sanitation is that there are significant negative externalities that are not easily understood and managed by households. People need sanitation services, which are often unaffordable, and household expenditures on sanitation are typically given lower priority compared to other essential needs. This results in open defecation and the improper disposal of untreated fecal matter (in a variety of forms). Managing human waste requires government intervention and regulation because of the inherent public health risks. Sewer systems are the most common response in cities in the global North and have some of the economic characteristics of a public good; for example, one additional person connecting to the system paying for service provides revenue for the utility with very few additional marginal costs.[213]

In very densely populated urban areas, the least expensive options, such as pits, are impractical. The middle cost options—including ventilated pit latrines and septic tanks—require the state to be highly capable of enforcing regulations, particularly because of the public health risks involved. Moreover, in many cases these middle cost options impose high costs on households (see Table A.4 in the Appendix for septic tank costs). Not all of these costs have to be imposed on households—the state could be responsible for emptying on-site sanitation—but global South cities rarely provide these services. Hence, people use private companies and informal providers to empty tanks and pits, but this waste is often disposed of in dangerous and illegal ways to avoid paying charges for proper treatment. Many urban policymakers turn a blind eye to this reality and continue on the assumption that the middle cost options are feasible and safe.

The state also needs to ensure that the method used to capture and contain fecal sludge on-site is safe. Given the need to develop government regulatory capacity, it may be that in the medium and long term, the approaches to sanitation with high, one-time, up-front capital investment costs (e.g., sewers) might be less expensive than the middle cost approaches.[214] On-site sanitation solutions require far more capacity on the part of local government and sanitation utilities in planning for accessible fecal sludge management treatment plants and to regulate and enforce safe practices—capacity that does not in reality often exist (see Box 7 for an example from Kenya). If the full cost of managing, regulating, and enforcing safe fecal sludge transport, treatment, and reuse or disposal were considered, it is unclear whether on-site sanitation solutions would still be considered inexpensive from the perspective of cities.

On the other hand, sewers require large-scale investment finance, and most households will not have the ability to pay full cost for the connection and service charges, and many governments lack finance as well as the ability to borrow. Conventional wisdom is that sewer systems are too expensive for low-income households.[215] However, the price of sewers reflects political and technical decisions that are neither transparent nor easy to understand.[216] In addition to the capital investment cost, the lack of attention paid to sewer expansion can also be attributed to a failure to acknowledge the relationship between a lack of access to safe, reliable, and affordable sanitation services and negative public health and environmental outcomes.

Finance

Constructing and expanding sewer systems and wastewater treatment plants is capital intensive and therefore requires substantial flows of investment finance. The fact that substantial urban populations in the global South are living in informal settlements elevates the need to find affordable sanitation solutions, which usually translates into tariff structures substantially below operating costs.[217] When national budgets lack fiscal resources, the burden of amortizing capital costs is usually assigned to the utility or municipality, which is rarely in a position to recover operating costs. The utility also needs to factor in service extensions to meet the demands of a growing urban population.

Box 7 | Innovative Financing to Ensure Sanitation Is Affordable in Kenya

In Kenya the national government established the Kenya Water Sector Trust Fund—a Kenyan state corporation mandated to finance water and sanitation infrastructure for the poor and under-served communities. To amplify the government's effort, the German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit) has been implementing the Upscaling Basic Sanitation for the Urban Poor Programme (UBSUP) in collaboration with the Kenya Water Sector Trust Fund.

As part of this program, households choose from different standardized toilet options, and the homeowner receives a financial incentive that covers part of the cost of building a toilet according to the standards. When the toilets are built according to the standard, the utility can connect a vacuum tanker that is licensed by the utility to provide collection and transport services to a treatment facility. If the urban area did not already have a treatment facility, UBSUP financially supports the construction of a decentralized treatment facility.

The program is currently being implemented in 25 towns across the country, providing access to safe sanitation for more than 150,000 Kenyans. At present, 13 decentralized wastewater and sludge treatment facilities and more than 14,000 toilets have been constructed. The program regularly conducts affordability assessments for poor households based on household expenditures.

Sources: Water Sector Trust Fund, 2018; SuSanA, n.d.a.

Although most sectoral policies recognize the critical importance of recovering operational costs, the political will to charge cost-recovering tariffs is usually absent if households cannot afford them. Moreover, if consumers were charged the full cost, these services would be unaffordable, would not be used, and thus would not achieve the desired outcomes.[218] As noted earlier, the cost of sewer networks and other sanitation-related services is in part political, but governments seem reluctant to acknowledge this reality and to provide subsidies that can ensure access for low-income households.[219]

Table 7 | **Sample of City Sewage and Fecal Sludge Management Operation and Maintenance Costs**

	CITY	SEWERAGE COVERAGE (% HH)	SEWERAGE SYSTEM BUDGET PER CAPITA ANNUALLY (US$)	SEWERAGE O&M BUDGET PER CAPITA ANNUALLY (US$)
CITY SEWAGE	Santiago de Cali	99	0.45	N/A
	Cochabamba	80	2.03	1.35
	Rio de Janeiro	65	13.8	N/A
	Bengaluru	79	20.79	1.26
	Mumbai	28	10.00	3.50
	Dhaka	18	15.6	4.70

	CITY	FSM COVERAGE (% HH)	FSM BUDGET PER CAPITA ANNUALLY (US$)	FSM O&M PER CAPITA ANNUALLY (US$)
FECAL SLUDGE	Kampala	85	12.87	8.15
	Lagos	94	0.32	.0035

Notes: Currency figures were converted to U.S. dollars using market exchange rates corresponding to the time of data collection (2017). FSM = fecal sludge management; HH = household; O&M = operations and maintenance. This analysis assumes that the sewage tariff only applies to households connected to sewers. However, in most cities, wastewater tariffs are combined with water bills.
Source: WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

Table 7 illustrates a sample of operations and maintenance (O&M) costs from the WRI 15-city study. In the table O&M costs are comparable between sewerage-based systems and on-site systems. It is common for cities to collect revenue through a wastewater or sanitation tariff often included as part of the household water bill. However, the revenue generated through this tariff will not cover all O&M sanitation costs.

In the countries of South Asia, for example, despite good economic growth rates in several cities, water and sewer tariffs are below operating cost recovery levels, so water and sanitation utilities are unable to survive without annual subsidies or fiscal transfers from central government budgets.[220] Urban water utilities and municipal departments are forced to rely on fiscal transfers and donor financing that are grossly insufficient to meet the sanitation needs.[221] The utility must seek approval for funding to undertake significant repairs or if emergencies arise outside of the annual budget.[222] In the absence of adequate cost recovery, finance for sanitation service and infrastructure from investors has not been forthcoming.

On the positive side, several low-income countries have implemented innovative contractual arrangements largely through civil society organizations and NGOs that build partnerships between communities, domestic private providers, and the water and sanitation utility, with each stakeholder contributing to innovative local solutions.[223] However, there are no organizational incentives to effectively design, implement, and manage infrastructure that connects these local efforts to citywide sanitation systems. In the context of the SDGs, achieving the much higher benchmarks of qualitative targets (compared to the Millennium Development Goals) requires rethinking the entire planning and implementation process.[224]

From an urban sanitation planning perspective, higher population densities mean that cities urgently require the expansion of sewer systems as well as alternative systems that deliver safe and affordable fecal sludge management. On-site sanitation systems must also be safely managed in the interim, which further requires regulatory, enforcement, and financial capacity.[225] Yet in areas of South Asia and sub-Saharan Africa, where a majority of the population depends upon on-site sanitation, the amount of finance for fecal sludge management is less than one-twentieth the investment in sewers, and the governance capacity to regulate complicated on-site sanitation systems is questionable.[226] Achieving the ambitious sanitation targets set out in the SDGs will require collaborative planning and active stakeholder engagement, significant financial investment in off-site as well as on-site sanitation systems, and the capacity to track and regulate the performance of the entire sanitation service chain.

8. SOLVING THE URBAN SANITATION CRISIS

Almost all governments within the United Nations have made commitments to provide for universal access to sanitation (and water) that go back more than 40 years.[227] So why in many nations has the urban population that lacks safely managed sanitation or in-home sewer connections *increased* since the year 2000? Part of the answer is that national governments and international agencies have not invested enough in sanitation for cities in the global South, especially given the growth of urban populations.

There is a significant underestimation of the magnitude of the urban sanitation crisis in the global South. The JMP sanitation categories should be revised to provide a more accurate and useful picture of sanitation practices, access, and risks to urban populations. City and sub-city level data are needed about who is responsible for what parts of the sanitation service chain as well as data on the availability and affordability of different sanitation services and practices from the perspective of the user. Criteria used to assess safety must take residential density into account. Cities, utilities, civil society, and other urban change agents need data collection systems that provide disaggregated and spatial sanitation information to galvanize action.

Prospective sources of relevant data that cities and national governments should support include more detailed sanitation questions on national censuses as well as water and sanitation census data made available to urban governments and other key local actors disaggregated to the street or ward level. Functioning vital registration systems and patient records from hospitals and health care centers should be providing detailed health data to local governments. Community-led mapping and profiling of informal settlements—which has been undertaken by Slum/Shack Dwellers International in thousands of informal settlements in close to 500 cities[228]—can provide detailed local data on sanitation and other key health determinants.

The need for sanitation is simple and shared by everyone, yet the best ways to meet this need differ widely depending on local contextual factors. There is insufficient recognition of the importance of context within discussions of sanitation by the United Nations and around the SDGs. This contributes to misunderstandings about the urban sanitation challenge and confusion about which actions can most appropriately address the urban sanitation crisis.

We suggest priority actions for cities, utilities, and other urban change agents that are concerned with the well-being of the urban under-served. First, cities should focus on extending the sewer network to households and communal and public toilets. Although off-site solutions place the least burden on a household in terms of cost and risk, they require the largest initial capital investment as well as a strong capacity for municipal planning, governance, and financial management on the part of local governments and sanitation utilities. Most struggling and emerging cities in the global South will require a combination of off-site and on-site sanitation solutions to meet the short- and medium-term needs of their growing populations.

Where private septic tanks, pit latrines, and containers are used, cities should create safe and affordable systems to regulate the emptying, transportation, treatment, reuse, and disposal of human waste. Most on-site solutions require less capital investment on the part of the city or national government. However, on-site sanitation solutions place enormous responsibility on individuals, households, and communities. Some policymakers will argue that governments can regulate on-site sanitation solutions and that on-site approaches will create opportunities for the private sector. However, on-site sanitation solutions require far more capacity to regulate on the part of local government and sanitation utilities—capacity that does not currently exist in most struggling and emerging cities.

During this period of transition, cities should lay the foundation for off-site sanitation solutions to work. These include settlement upgrading, regularizing the spatial layout of housing plots, planning access roads for new developments, and legalizing informal settlements where there are not immediate overriding safety concerns. Cities should work with communities to implement simplified sewage and communal septic tanks where the conditions are supportive and with a plan to eventually connect these to a citywide sanitation system.

Finally, the priority action areas outlined in this paper need to be coupled with efforts to protect water sources, including groundwater and surface water (which should be regularly tested), and better management of solid waste. Cities must also work on providing adequate sanitation services outside the home. Achieving the optimal combination of sanitation approaches will require balancing what is reasonable in a given local context, minimizing risks to public health and the environment, and ensuring the entire sanitation service chain is affordable and regulated, all while shifting responsibility away from individual users and households to the public sector.

APPENDIX

Table A.1 | **City Sanitation Utilities, Sewage Treatment, and Fecal Sludge Treatment**

CITY NAME	IS THERE A MUNICIPAL SYSTEM FOR TREATING SEWAGE?	NO. OF AGENCIES RESPONSIBLE FOR FECAL SLUDGE AND/ OR SEWAGE TREATMENT	MANAGE-MENT	NO. OF WWTP	NO. OF FSTP	NO. OF COLOCATED PLANTS	NO. OF WWTPS THAT ACCEPT SEPTIC TANK/ PIT SLUDGE	FUNCTION-ALITY	TREATMENT PROCESS
SUB-SAHARAN AFRICA									
Kampala	Yes	1	Public	2	2	0	2	High	Conventional sewage treatment works (primary treatment, secondary sewage purification); sewage stabilization ponds
Lagos	Yes	1	Public, private	Public: 5 Private: 400+	public: 21	0	Most	Low	Preliminary treatment, coagulation-flocculation separation, primary treatment for most; secondary treatment for 4 plants
Maputo	Yes	1	PPP	1	0	0	1	Low	Stabilization ponds (2 anaerobic, 2 facultative) but work inefficiently
Mzuzu	Yes	1	Public	4	1	0	0	Moderate	The localized small WWTPs send sewage to a dam for natural treatment; the FSTP uses 3 stabilization ponds
Nairobi	Yes	1	Public	1	1	0	1	High (WWTP), low (FSTP)	Stabilization pond treatment process, conventional biological aeration for fecal sludge
SOUTH ASIA									
Bengaluru	Yes	1	Public	24	0	10	0	Moderate–high	Primary treatment, secondary (aeration tanks), sludge digesting and drying at 2 tertiary plants; digested sludge is sent to farms to use as manure; two sludge-to-energy plants
Colombo	No	1	n/a	0	0	0	0	n/a	n/a
Dhaka	Yes	1	Public	0	1	0	0	Low	Primary treatment, secondary (facultative and sludge lagoons), tertiary disinfection of discharge
Karachi	Yes, but only partly functional	1	Public	4, but only 1 is partly functional	0	0	0	Very low	Untreated wastewater discharged into sea
Mumbai	Yes	1	Public	12	0	0	6	High	Preliminary treatment, then to aerated lagoons or marine outfall for 7 plants; rotating media biological reactor and aerobic treatment for 4 reuse recycle plants; 1 soil biotechnology plant

Table A.1 | **City Sanitation Utilities, Sewage Treatment, and Fecal Sludge Treatment (continued)**

	CITY NAME	IS THERE A MUNICIPAL SYSTEM FOR TREATING SEWAGE?	NO. OF AGENCIES RESPONSIBLE FOR FECAL SLUDGE AND/ OR SEWAGE TREATMENT	MANAGE-MENT	NO. OF WWTP	NO. OF FSTP	NO. OF COLOCATED PLANTS	NO. OF WWTPS THAT ACCEPT SEPTIC TANK/ PIT SLUDGE	FUNCTION-ALITY	TREATMENT PROCESS
LATIN AMERICA	Caracas	No	1	n/a	0	0	0	0	n/a	n/a
	Cocha-bamba	Yes	1	Public	1	0	0	1	Moderate	5 oxidation lagoons
	Rio de Janeiro	Yes	2	Public, private	24	0	0	2	High (21), moderate (3)	Conventional centralized system with several models: 20 plants use activated sludge, 2 plants use a submarine emissary, and the remaining use biological treatment
	São Paulo	Yes	1	Public-private	4	0	0	4	High	Preliminary treatment, primary clarifier, activated sludge, secondary clarifier
	Santiago de Cali	Yes	1	Public	1	0	0	1	High	Advanced primary treatment followed by anaerobic digestion to produce biogas; produces 95% of the plant's energy needs

Notes: FSTP = fecal sludge treatment plant; n/a = not applicable; WWTP = wastewater treatment plant. Functionality is categorized as *high* if primary treatment is operating more than 80 percent of the year, *moderate* if primary treatment is more than 50 percent, and *low* if primary treatment is below 50 percent.

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[229]

Table A.2 | **Household Access to Off-Site and On-Site Sanitation and Open Defecation**

Region	CITY NAME	OFF-SITE SANITATION					ON-SITE SANITATION						OPEN	OVERALL	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
		% HH with access to city's sewer system	% HH waste-water sent to treat-ment	% HH waste-water treated at STP	% HH waste-water collected but un-treated at STP	Location of un-treated wastewa-ter dis-charge	% HHs that use on-site meth-ods	% HH fecal sludge emp-tied	% HH fecal sludge deliv-ered to treat-ment	% HH fecal sludge treated at STP	% HH fecal sludge untreat-ed	Location of untreat-ed fecal sludge discharge	% HH: open defe-cation	Total safely man-aged (%)	Total un-safely man-aged (%)
SUB-SAHARAN AFRICA	Kampala	10	10	10	0	n/a	90	85	19	19	71	Lake, buried, stream	0	29	71
	Lagos	0	0	0	0	n/a	98	94	70	45	51	Lake, riv-ers, soil	2	45	55
	Maputo	9	9	6	3	Rivers	90	90	3	3	87	Streams, buried	1	9	91
	Mzuzu	0	0	0	0	n/a	100	16	16	16	84	Farms, buried, flooded out	0	16	84
	Nairobi	48	48	34	14	Rivers	52	49	6	6	46	Stream, buried, farms	0	40	60
SOUTH ASIA	Bengaluru	79	79	37	42	Lake	18	17	0	0	18	Farms, streams, lake, buried	3	37	63
	Colombo	39	0	0	39	Sea	60	60	0	0	60	Sea	1	0	100
	Dhaka	18	18	3	15	Rivers	82	82	0	0	82	Rivers, buried, low-lying areas	0	3	97
	Karachi	75	0	0	75	Streams, sea	10	10	0	0	10	Streams, sea	15	0	100
	Mumbai	28	28	28	0	Sea	62[a]	49	28	28	34	Stream, buried, flooded out, sea	10	56	44
LATIN AMERICA	Caracas	97	0	0	97	Rivers	2	2	0	0	2	Nearby streams	1	0	100
	Cochabamba	80	48	48	32	Rivers	20	20	20	12	8	Rivers	0	60	40
	Rio de Janeiro	53	53	53	0	Sea	42[a]	17	16	16	26	Buried	5	69	31
	São Paulo	87	65	65	22	Streams	13[a]	13	2	2	11	Buried, streams	0	67	33
	Santiago de Cali	99	87	87	12	Rivers	1	1	0	0	1	Buried	0	87	13

Notes: HH = household; n/a = not applicable; STP = sewage treatment plant. Lagos, Mzuzu, and Nairobi have pit latrines with fecal sludge that is contained, but never emptied.

a. Mumbai, Rio de Janeiro, and São Paulo are the only three cities with available data on "self-provisioned drain to waterway." This has been included as "on-site sanitation."

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[230]

Table A.3 | **Septic Tank and Pit Latrine Use and Proximity to Water Sources**

Region	CITY NAME	Percentage of Households Using Pit Latrines	Primary Materials Used to Line Pit Latrines	Percentage of Households Using Ground, Surface Water	INFORMAL SETTLEMENT NAME	Percentage of Households Using Septic Tanks	Septic Tanks Are Located Less than 50 m from [...]	Percentage of Households Using Pit Latrines	Materials Used to Line Pit Latrines	Pit Latrines Are Located Less than 30 m from [...]	Percentage of Households Using Ground, Surface Water
SUB-SAHARAN AFRICA	Kampala	60	Bricks and mortar, reinforced concrete	15	Kalimali	20	Canals, shallow wells, streams	80	No lining	Canals, shallow wells, streams	10
SUB-SAHARAN AFRICA	Lagos	34	Concrete	69	Makoko	25	Lagoon	75	Concrete	Lagoon	70
SUB-SAHARAN AFRICA	Maputo	41	Drums, tires, no lining	30	Nhlamankulu D	44	Reservoirs, shallow wells, boreholes	56	Drums, tires, no lining	Reservoirs, shallow wells, boreholes	0.5
SUB-SAHARAN AFRICA	Mzuzu	84	No lining	0	Zolozolo West Ward	5	Rivers, shallow wells, deep wells, boreholes	95	No lining	Rivers, shallow wells, deep wells, boreholes	53
SUB-SAHARAN AFRICA	Nairobi	40	Stones, no lining	8	Kosovo Village in Mathare Valley	0		1	No lining	Rivers	0
SOUTH ASIA	Bengaluru	11	Not available	17	Koramangala	0		0			20
SOUTH ASIA	Colombo	1	Drums	1.5	Borella South	49	Rivers, canals	0			2
SOUTH ASIA	Dhaka	4	Reinforced concrete, no lining	1	Kallyanpur Pora Basti	97	Boreholes	3	Concrete slabs and rings	Boreholes	0.5
SOUTH ASIA	Karachi	0		10	Ghaziabad Sector 11½, Orangi Town	0		0			6.5
SOUTH ASIA	Mumbai	1	Old plastic and metal sheets, jute, old clothing	8	Siddarth Nagar	0		0			22.5
LATIN AMERICA	Caracas	0		1	Terrazas del Alba	0		0			0
LATIN AMERICA	Cochabamba	0		0	San Miguel Km4	10	None	0			5
LATIN AMERICA	Rio de Janeiro	1	No lining	1	Rocinha	1	Rivers, canals	2	No lining	Rivers, canals	1
LATIN AMERICA	São Paulo	0		0	Jardim São Remo	1	Rivers	0			0
LATIN AMERICA	Santiago de Cali	1	Stones	0	Comuna 20	0		1	Stones	Rivers	0

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[231]

Table A.4 | **Cost of On-Site Sanitation Construction and Fecal Sludge Removal**

CITY NAME	METHOD	CONSTRUCTION COSTS (US$)	REMOVAL METHOD	COST TO EMPTY ONE TIME (US$)
Kampala	Private septic tank 4-stance[a]	3,299	Pump out	58
	Communal septic tank 4-stance	4,123	Pump out	58
	Pit latrine 4-stance VIP 4-stance slab	1,457 1,405	Pump out, small gulper tech; no removal	10; 0
	Composting toilet	2,749	Manual	10
Lagos	Private septic tank	1,490	Pump out	53
	Pit latrine VIP slab no slab	1,192 89 75	Manual: VIP slab Buried, no removal	45 16 0
	Hanging latrine	0	Direct to waterway	0
Maputo	Private septic tank	462	Small gulper tech Manual Pump out (vacuum truck)	23 8 97
	Pit latrine slab no slab	70 16	Small gulper tech Manual	23 8
Mzuzu	Private septic tank	683	Pump out	25
	Pit latrine VIP slab no slab	410 205 68	Flooding out; no removal	27; 0
	Composting toilet	273	Manual, no removal	0
Nairobi	Private septic tank concrete plastic biodigester	1,987 662	Pump out	43
	Communal septic tank	2,838	Pump out	43
	Pit latrine VIP slab	402 378	Manual, pump out, small gulper tech; flooding out	43; 0

Table A.4 | **Cost of On-Site Sanitation Construction and Fecal Sludge Removal (continued)**

INFORMAL SETTLEMENT NAME	METHOD	CONSTRUCTION COSTS (US$)	REMOVAL METHOD	COST TO EMPTY ONE TIME (US$)
Kalimali	Private septic tank	687	Pump out	76
	Pit latrine	687	Pump out; no removal	96; 0
Makoko	Private septic tank	1,490	Pump out	45
	Pit latrine VIP slab	 1,192 894	Pump out	45
Nhlamankulu D	Private septic tank	118	Small gulper tech Manual	23 8
	Pit latrine slab No slab	 70 16	Small gulper tech Manual	23 8
Zolozolo West Ward	Private septic tank	615	Pump out	25
	Pit latrine VIP slab No slab	 410 137 68	No removal	0
	Composting toilet	273	Manual, no removal	0
Kosovo Village in Mathare Valley	Pit latrine	slab: 189	Manual	7
	Self-provisioned drain	114	Directly to waterway	Shack: 118 Block: 213

SUB-SAHARAN AFRICA

Table A.4 | **Cost of On-Site Sanitation Construction and Fecal Sludge Removal (continued)**

	CITY NAME	METHOD	CONSTRUCTION COSTS (US$)	REMOVAL METHOD	COST TO EMPTY ONE TIME (US$)
SOUTH ASIA	**Bengaluru**	Private septic tank	427	Pump out	29
		Pit latrine	89	Pump out	19
	Colombo	Private septic tank	645	Manual, pump out	24
		Pit latrine	24	Manual, pump out	24
	Dhaka	Private septic tank	593	Manual, connected to drainage	24
		Communal septic tank	711	Manual Vacutug truck Connected to drainage	59 95 0
		Pit latrine Slab single pit	24	Manual	18
	Karachi	Private septic tank[b]	165	Manual	565
		Communal septic tank	108	Manual	47
	Mumbai	Private septic tank	466	Manual	116
		Communal septic tank	349	No removal	0
		Pit latrine VIP No slab	70 23	No removal	0
		Self-provisioned drain	171	Direct to waterway	0
LATIN AMERICA	**Caracas**[c]	Private septic tank	485	Pump out, manual	97
	Cochabam-ba	Private septic tank	210	Manual	252
	Rio de Janeiro	Private septic tank	733	Pump out	141
		Pit latrine no slab (10 seats)	879	No removal	0
		Self-provisioned drain	612	Direct to waterway	0
	São Paulo	Private septic tank	625	Pump out, manual, gulper tech	313
		Self-provisioned drain	281	Direct to waterway	0
	Santiago de Cali	Pit latrine[d]	–	No removal	0

Table A.4 | Cost of On-Site Sanitation Construction and Fecal Sludge Removal (continued)

Region	Informal Settlement Name	Method	Construction Costs (US$)	Removal Method	Cost to Empty One Time (US$)
South Asia	**Koramangala**	No on-site methods			
South Asia	**Borella South**	Private septic tank	968	Pump out	23
South Asia	**Kallyanpur Pora Basti**	Private septic tank	593	Manual, pump out, connected to drainage	24
		Communal septic tank	2,135	Manual, pump out	96
		Pit latrine	36	Manual	6
South Asia	**Ghaziabad Sector 11 ½, Orangi Town**	Self-provisioned drain	122	Direct to waterway	28
South Asia	**Siddarth Nagar**	Self-provisioned drain	23	Direct to waterway	0
Latin America	**Terrazas del Alba**	No on-site methods			
Latin America	**San Miguel Km4**	Private septic tank	280	Manual	210
Latin America	**Rocinha**	Private septic tank[e]	n/a	Pump out	141
		Pit latrine	n/a	No removal	0
		Self-provisioned drain	532	Direct to waterway	0
Latin America	**Jardim São Remo**	Private septic tank	312	Vacuum truck	219
		Self-provisioned drain	156	Direct to waterway	0
Latin America	**Comuna 20**	Pit latrine[d]	–	No removal	0

Notes: n/a = not applicable; VIP = ventilated improved pit. All costs reported in U.S. dollars. Currency figures were converted to U.S. dollars using market exchange rates corresponding to the time of data collection (2017).

a. Four-stance toilet blocks are typically shared latrines for rentals. Based on the selected informal settlement, four-stance toilet blocks serve 8–15 households. Individual households do not pay for the cost of construction. In some areas of the city, households will construct two-stance toilet blocks, but an average cost of two-stance toilets was not available.

b. Private septic tank costs are higher than communal septic tanks because septic tanks are typically constructed on land that is publicly owned or with no administrative authorization for construction, and the private owner must pay an extra amount to the municipal official to earn permission. Some communities work collectively and are able to negotiate a better deal with the municipal staff.

c. Costs from Caracas were converted using the black market exchange rate during the time of data collection: December 2017 (Bs103,024 to US$1).

d. Pit latrines in Santiago de Cali are now abolished; construction costs are not available.

e. Private septic tanks are no longer constructed. For the few buildings with private septic tanks, the cost was included in the building cost.

Source: Based on the WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.[232]

ENDNOTES

1. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.
2. WHO and UNICEF, 2017; Mara and Evans, 2018.
3. Beard et al., 2016.
4. In this paper, we use the term *global South* to broadly refer to the regions of Africa, Asia, Latin America, and Oceania, referring less to geography and more to a shared empirical context that emerges from shared economic and political histories, signifying less development than the advanced early urbanizing economies. See Dados and Connell, 2012: 12–13.
5. Mills et al., 2018.
6. WHO, 2018.
7. WHO, 2012; Wee, 2018.
8. Perard, 2018: 23.
9. Perard, 2018: 23.
10. Perard, 2018: 23.
11. Hutton, 2011; WHO, 2012.
12. UN-Water, 2008: 1.
13. WHO, 2012: 8.
14. Nyenje et al., 2010.
15. Nyenje et al., 2010: 447; 2013: 15.
16. Beard et al., 2016.
17. Mitlin et al., 2019: 20.
18. See Banana et al. (2015a: 1), supported by interviews with Slum/Shack Dwellers International (SDI) community leaders.
19. Banana et al., 2015a: 52.
20. Lilford et al., 2017; Satterthwaite et al., 2018a.
21. Peal et al., 2014b.
22. UN DESA, 2017.
23. Berendes et al., 2018: 2.
24. Berendes et al., 2018: 2.
25. UNICEF and WHO, 2015a: 76; Mara and Evans, 2018.
26. WHO, 2018.
27. Mills et al., 2018: 2.
28. WHO, 2018.
29. Cairncross, 2018: 85.
30. Berendes et al., 2018: 2; Mills et al., 2018: 2; SuSanA, 2018c.
31. Mills et al., 2018.
32. Mills et al., 2018: 2; WHO, 2018: 125; Buckley and Kallergis, 2019.
33. Wee, 2018. The World Health Organization estimates these economic losses at $260 billion per year (WHO, 2012).
34. Perard, 2018: 23.
35. WSP, 2018.
36. Perard, 2018: 23.
37. UN-Water, 2015.
38. Perard, 2018: 23.
39. Perard, 2018: 23.
40. Hutton, 2011; WHO, 2012.
41. UN-Water, 2008: 1.
42. WHO, 2012: 8.
43. Kimmelman, 2017; WHO, 2018.
44. Nyenje et al., 2010: 447; 2013: 15.
45. Nyenje et al., 2010.
46. Nyenje et al., 2010: 447–48.
47. Beard et al., 2016.
48. Tilley et al., 2014.
49. Tilley et al., 2014.
50. The World Resources Report (WRR) *Towards a More Equal City* categorized 769 cities as *struggling*, *emerging*, *thriving*, and *stabilizing*. Struggling and emerging cities currently have lower incomes per capita, and this trend is projected to continue through 2030. For a detailed explanation of the city categories, see Beard et al. (2016).
51. There are exceptions in urban or peri-urban areas with low population densities and where house plot sizes are large.
52. SuSanA, 2018c.
53. UNICEF and WHO, 2015.
54. Struggling and emerging cities have low GDP per capita today; however, struggling cities, compared to emerging cities, have a lower GDP per capita to projected growth in population between 2015 and 2030. Thriving cities have a high GDP per capita today, and a high ratio of projected growth in GDP per capita to projected growth in population between 2015 and 2030. See Beard et al. (2016: 10).
55. SuSanA, 2018c.
56. For SFDs from 50 African, Asian, and Latin American cities, see the SFD Promotion Initiative database at sfd.susana.org.
57. For example, SFD researchers found that in Dhaka, Bangladesh, slum dwellers overwhelmingly dispose excreta in open drains, and in Hawassa, Ethiopia, a smaller city, slum dwellers can still dig new pits. For Dhaka, see SuSanA (2018a), and for Hawassa, see SuSanA (2018b).
58. For more information on how SFDs are calculated, see SuSanA (n.d.b).
59. WHO and UNICEF, 2018.
60. NPC and ICF International, 2014.
61. WHO and UNICEF, 2017: 86.
62. WHO and UNICEF, 2017: 92.

63. WHO and UNICEF, 2017: 106.
64. WHO and UNICEF, 2017.
65. WHO and UNICEF, 2015, 2017.
66. Bartram et al., 2018; Buckley and Kallergis, 2019.
67. WHO and UNICEF, 2017: 15.
68. Bartram et al., 2018; Buckley and Kallergis, 2019.
69. WHO and UNICEF, 2015.
70. WHO and UNICEF, 2015.
71. Jenkins et al., 2014.
72. Satterthwaite et al., 2018b.
73. Hasan, 2006; Peal et al., 2014; Evans et al., 2017; Lwasa and Owens, 2018; SuSanA, 2018c.
74. The JMP is currently working to develop an affordability measure.
75. Beard et al., 2016.
76. For the remainder of the paper when referring to the “case within the case” in each of the 15 cities, the term *informal settlement* is used broadly to refer to informal settlements and low-income neighborhoods. For example, in Cochabamba the term *informal settlement* is not used to describe poor residential neighborhoods, and San Miguel is considered a low-income neighborhood.
77. **Caracas:** INE Venezuela, 2011a. Interview: Community leader, Terrazas del Alba, July 2017. **Cochabamba:** INE Bolivia, 2011. Interview: Administrator, Drinking Water Association of San Miguel Km4, March 2017. **Rio de Janeiro:** IBGE, 2009, 2010. Interviews: Community leaders, Rocinha, July 2017. **São Paulo:** IBGE, 2010; Prefeitura Municipal de São Paulo, 2017a, 2017b. **Santiago de Cali:** Municipality of Santiago de Cali, 2017. **Bengaluru:** Office of the Registrar General & Census Commissioner, n.d. Interview: Community leader, Slum Jagatthu, July 2017; Community leader, Koramangala, July 2017. **Mumbai:** Directorate of Census Operations, 2011; ICDS, 2016; WIEGO, 2018. **Colombo:** DCS, 2010. **Karachi:** PBS, 2017. Interviews: Representative, Technical Training Resource Centre; Community leaders, Ghaziabad Sector, July 2017. **Dhaka:** BBS, 2011; WSUP, 2016a. **Kampala:** Government of Uganda, 2016; ACTogether Uganda et al., n.d. **Lagos:** LBS, 2013. **Maputo:** Population figure is based on preliminary results of the 2017 census; Conselho Municipal de Maputo, 2010; INE Mozambique, 2006, 2010, 2012, 2015; WSUP, 2016b. **Mzuzu:** NSO, 2010; UN-Habitat, 2011; Mzuzu City Council, 2017. **Nairobi:** KNBS, 2010, 2019; NCC, 2014; Cira et al., 2016. Interview: Community leader, Kosovo Village, July 2017.
78. For a more in-depth discussion on urban land growth, see the WRR paper on urban expansion (Mahendra and Seto, 2019.)
79. Chen and Beard, 2018.
80. WRI Ross Center for Cities’ Water and Sanitation 15-City Study, 2018.
81. It should be noted that the informal settlement in Karachi, Orangi, is an example of an informal settlement that has had active community participation in sanitation for more than 30 years; see Hasan (2006). For more information see Section 6.1.
82. **Caracas:** INE Venezuela, 2011b; Interviews: Community leaders, Terrazas del Alba, July 2017. **Cochabamba:** Interview: Regulator, National Water Authority; Administrator, Drinking Water Association, San Miguel Km4, March 2017. **Rio de Janeiro:** Interviews: Representative, CEDAE-STS Alegria; Director, Rocinha Health Office, July 2017. **São Paulo:** IBGE, 2010b; Prefeitura Municipal de São Paulo, 2017b; see Sabesp, http://site.sabesp.com.br/site/Default.aspx. **Santiago de Cali:** Municipality of Santiago de Cali, 2017. Interview: Community leader, Comuna 20, July 2017. **Bengaluru:** BWSSB, 2011; Interviews: Community leader, Koramangala; Representative, BWSSB, July 2017. **Mumbai:** Interviews: Community leaders, Siddarth Nagar; Campaign leaders, Pani Haq Samiti (Committee for Water Right), July 2017. **Colombo:** DCS, 2010. Interviews: Statistician, Department of Census and Statistics; Administrator, Grama Niladhari, Borella South, July 2017. **Karachi:** Interviews: Community leaders, Ghaziabad, July 2017. **Dhaka:** PMID, 2013. Interviews: Community leaders, Kallyanpur Pora Basti; Representative, NDBUS (Slum Committees), September 2017. **Kampala:** Interview: Representatives, KCCA and ACTogether; Community leaders, Kalimali, July 2017. **Lagos:** LBS, 2013. Interviews: Makoko Representative, Nigeria Red Cross Society; Representative, Lagos State Waste Water Office, July 2017. **Maputo:** Interviews: Water and Sanitation Specialist, World Bank; Sanitation manager, Municipality Drainage Office, July 2017. **Mzuzu:** Interview: Community leaders, Zolozolo West Ward, July 2017. **Nairobi:** Interviews: Community leaders, Kosovo Village, May 2017.
83. Mitlin et al., 2019: 20.
84. Mitlin et al., 2019: 20.
85. Mitlin et al., 2019.
86. Furlong, 2016; Ross et al., 2016.
87. Mitlin et al., 2019: 20.
88. Mitlin et al., 2019: 20.
89. The JMP assumes that excreta from households that report having sewer connections reach a sewer line and are transported as wastewater to a treatment plant. See WHO and UNICEF (2017: 29–30).
90. Based on WHO guidelines.
91. In this context we refer to on-site sanitation as a cost instead of a price because households are self-providing their sanitation solutions and the price is not solely mediated by the market. Typically, the term *cost* is associated with production and the term *price* with the amount the consumer pays when transactions are mediated by the market. However, in the context of what households pay for sanitation, this distinction is not always clear because of the mix of self-providing, obtaining through informal means and transactions, and purchasing sanitation services or a portion of them from a public or private entity. Throughout the paper, when referring to the literature, we tend to follow the language used in the original documents.
92. To facilitate ease of interpretation, all costs are calculated using market exchange rates.
93. There are also very rudimentary latrines that cost almost nothing—shallow pits, four posts, and material walls.

94. **Caracas**: INE Venezuela, 2011b. Interviews: Community leaders, Terrazas del Alba, July 2017. **Cochabamba:** Interviews: Environmental Regulator, National Water Authority; Administrator, Drinking Water Association, San Miguel Km4, March 2017. **Rio de Janeiro:** IBGE, 2010a. Interview: Representative, CEDAE-STS Alegria; Representative, Rio Aguas Foundation; Representative, Rocinha Health Office, July 2017. **São Paulo:** Whately and Diniz, 2009; IBGE, 2010b. Interview: Specialist in São Paulo household construction, July 2017. **Santiago de Cali:** Municipality of Santiago de Cali, 2017; see Empresas Municipales de Cali, www.emcali.com.co., n.d. Interview: Community leader, Comuna 20, July 2017. **Bengaluru:** BWSSB, 2011. Interview: Community leader, Koramangala, July 2017. **Mumbai:** Directorate of Census Operations, 2011. Interviews: Officer, Sanitation Department, MCGM; Community leaders, Siddarth Nagar; July 2017. **Colombo:** DCS, 2010. Interview: Engineer, Colombo Municipal Council, July 2017. **Karachi:** Interviews: Staff representative, Orangi Pilot Project; Community leaders of Orangi and Baldia; Director, Urban Resource Center; Community leaders, Ghaziabad, July 2017. **Dhaka:** PMID, 2013; Barkat et al., 2014; WSUP, 2015. Interviews: Consultant, World Bank; Representative, WSUP-Dhaka; Community leaders, Kallyanpur Pora Basti; Representative, NDBUS (Slum Committees), September 2017. **Kampala:** Interview: Representatives, NWSC; Representatives, KCCA; Representative, ACTogether; Representative, CIDI; Community leaders, Kalimali, July 2017. **Lagos:** LBS, 2013. Interviews: Manager, Lagos State Waste Water Office; Makoko Representative, Nigeria Red Cross Society, July 2017. **Maputo:** WSP and Municipality of Maputo, 2014. Interviews: Water and Sanitation Specialist, World Bank; Sanitation Manager, Municipality Drainage Office, July 2017. **Mzuzu:** NSO, 2010. Interviews: Community leaders, Zolozolo West Ward; Officer, National Statistics Office, July 2017. **Nairobi:** Interviews: Community leaders, Zolozolo West Ward, KNBS, 2012.

95. UN and WSSCC, n.d.

96. Mitlin et al., 2019.

97. Mitlin et al., 2019.

98. See Banana et al. (2015a), supported by interviews with SDI community leaders.

99. WSUP, 2013; Scott et al., 2015.

100. Sanergy is a local toilet business that hires local people to manufacture and operate low-cost, high-quality toilets for Nairobi's slums.

101. Satterthwaite, 2015: 11.

102. Banana et al., 2015b: 52.

103. Banana et al., 2015b.

104. Banana et al., 2015b.

105. Banana et al., 2015b.

106. For more information on cost estimations of sanitation in the global South, see the Bill & Melinda Gates Foundation and University of Leeds project CACTUS, https://cgd.leeds.ac.uk/research/infrastructurebasicservices/.

107. The UK government uses a discount rate of 3.5 percent up to 30 years, 3 percent between 31 and 75 years, and 2.5 percent between 76 and 125 years, with the rate falling to 1 percent eventually. (See the government's "Green Book Supplementary Guidance: Discounting," https://www.gov.uk/Government/Publications/Green-Book-Supplementary-Guidance-Discounting.) The benefits from sewer networks clearly last a long time before replacement networks are required. If the benefits received in year 40 are costed today, they are only worth 2 percent of their future value if a discount rate of 10 percent is used; if the discount rate is 3.5 percent, then they are worth 25 percent of their future value today, and if the discount rate falls to 1 percent, then they are worth 67 percent of their future value when assessed today.

108. Weitz et al., 2016.

109. Figures were converted using the 2011 Organisation for Economic Co-operation and Development market exchange rate: ₹46.67 to $1.

110. Weitz et al., 2016.

111. Weitz et al., 2016.

112. CPHEEO, 2005.

113. Weitz et al., 2016.

114. Weitz et al., 2016.

115. Weitz et al., 2016.

116. It can be argued that some on-site are less expensive because they ignore the costs of securing compliance with safety and environmental regulations. If the relevant authorities include the costs of regulating and managing these systems, the cost would rise. Without supervision, on-site solutions will have associated public health risks.

117. Lilford et al., 2017; Satterthwaite et al., 2018a.

118. Esrey et al., 1998; McGranahan, 2002.

119. This comes from the authors' experience attending many conferences and seminars where environmentalists refuse to accept sewer systems. This is also discussed in Tesh and Paes-Machado (2004).

120. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.

121. Water services are discussed in-depth in another WRR working paper on water access in the global South; see Mitlin et al. (2019).

122. Uytewaal, 2016.

123. Water services are discussed in-depth in another WRR working paper on water access in the global South; see Mitlin et al. (2019).

124. Goldfrank, 2011.

125. Goldfrank, 2011.

126. Genser, 2008: 1638.

127. Almansi, 2009; Hardoy and Ruete, 2013.

128. Cabannes, 2015.

129. Beard et al., 2008.

130. For a discussion on the need for a better understanding of local power and politics in relation to sanitation, see Kennedy-Walker et al. (2015).

131. King et al., 2017.
132. Mahendra and Seto, 2019.
133. See Section 6.3 on upgrading informal settlements.
134. Sinnatamby, 1990.
135. Bakalian et al., 1994.
136. Bakalian et al., 1994; Melo, 2005.
137. Melo, 2005.
138. Melo, 2005: 16.
139. Mathys, 2009.
140. Rydén et al., 2017.
141. Godfrey and Reed, 2013.
142. Rydén et al., 2017: 65.
143. Rydén et al., 2017: 67.
144. Rydén et al., 2017.
145. Hasan, 2008; Satterthwaite and Mitlin, 2014; Hasan and Arif, 2018.
146. Satterthwaite and Mitlin, 2014.
147. Hasan, 2006.
148. This is about Rs1,000–Rs4,000. Figures in U.S. dollars were converted using the market exchange rate in December 2012 (Rs97 to $1).
149. This is about Rs100–Rs300. Figures in U.S. dollars were converted using the market exchange rate in December 2012 (Rs97 to $1).
150. Hasan, 2008.
151. McGranahan and Mitlin, 2016.
152. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.
153. These tanks may be single- or multichambered, partially lined or fully lined, and may have an open bottom. If the bottom is open, this means they effectively operate as a soak pit, with little treatment; see SuSanA (2018c).
154. AECOM and Sandec/Eawag, 2010; Ariffin and Sulaiman, 2015.
155. Nelson and Murray, 2008.
156. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.
157. World Bank, 2013a.
158. Blackett et al., 2013.
159. World Bank, 2013a.
160. World Bank, 2013a.
161. World Bank, 2013a.
162. World Bank, 2013a.
163. World Bank, 2013a.
164. World Bank, 2013a.
165. Strauss and Montangero, n.d.
166. Strauss and Montangero, n.d.
167. Strauss and Montangero, n.d.
168. Nguyen et al., 2011.
169. DPWH, 2013.
170. DPWH, 2013.
171. Orejas, 2017.
172. Orejas, 2017.
173. Ortuste, 2012.
174. Ortuste, 2012.
175. Ortuste, 2012.
176. Jenkins et al., 2014.
177. Jenkins et al., 2014.
178. Jenkins et al., 2015.
179. Thye et al., 2011; Akvopedia, 2015.
180. Jenkins et al., 2015: 2590.
181. Jenkins et al., 2014.
182. WRI Ross Center for Sustainable Cities' Water and Sanitation 15-City Study, 2018.
183. Jenkins et al., 2014, 2015; Chunga et al., 2016.
184. Lwasa and Owens, 2018.
185. Lwasa and Owens, 2018.
186. Lwasa and Owens, 2018.
187. Russel et al., 2015.
188. Russel et al., 2015.
189. Russel et al., 2015.
190. Russel et al., 2015.
191. Banana et al., 2015b.
192. Russel et al., 2015.
193. Russel et al., 2015.
194. Russel et al., 2015: 10.
195. Russel et al., 2015.
196. Remington et al., 2018.
197. Remington et al., 2018: 3.
198. Remington et al., 2018; SOIL, 2018. SOIL uses both approaches of ecological sanitation and container-based sanitation, and refers to them interchangeably. To learn more, see the SOIL website, https://www.oursoil.org.
199. Hersher, 2017a, 2017b.
200. Remington et al., 2018: 3.

201. Greenland et al., 2016.

202. Greenland et al., 2016.

203. Greenland et al., 2016.

204. Greenland et al., 2016.

205. Banana et al., 2015a, 2015b.

206. Lwasa and Owens, 2018.

207. Lilford et al., 2017; Satterthwaite et al., 2018a.

208. Boonyabancha, 2005; Shand, 2017.

209. SDI, 2018.

210. SDI, 2018.

211. Archer, 2012; Papeleras et al., 2012.

212. Archer, 2012; Papeleras et al., 2012.

213. Buckley, 2017.

214. OECD, 2013.

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ACKNOWLEDGMENTS

We are grateful to Ani Dasgupta, Anjali Mahendra, and Robin King for providing comments on multiple drafts of the paper. We thank the internal and external reviewers who strengthen the paper. Internal reviewers were Sahana Goswami, Anne Maasen, Renata Mason, and Lubaina Rengwala. We are particularly thankful to Vijay Jagannathan for his insights and help with the text on sanitation finance and regulation. We are also grateful to the external reviewers: Katrin Bruebach, Robert Buckley, Myles Elledge, Barbara Evans, Mai Flor, Peter Mutale, and Alyse Schrecongost.

We are deeply grateful to the 16 local researchers who collected the data that became the empirical basis for the paper. These researchers include Ibidun Adelekan, Afnan Agramont Akiyama, Noman Ahmed, Md. Akhtaruzzamen, Carlos Aponte, Shriya Bhatia, Radha Chanchani, Tomaz Kipnis, Shuaib Lwasa, Gustavo Machado, Mtafu Manda, Baraka Mwau, Lina Maria Olaya Ortiz, Christina Semasinghe, Clara dos Santos Dimene, and Sachin Tiwale.

We thank the participants from the WRI Urban Water and Sanitation Workshop in July 2017: Ibidun Adelekan, Afnan Agramont Akiyama, Graham Alabaster, Vittal Boggaram, Chris Buckley, Arif Hasan, Vijay Jagannathan, Neil Jeffery, Marion Jenkins, Ranjiv Khush, Pawan Labhasetwar, Shuaib Lwasa, Brenda Medeiros, Gabriela Morales, Baraka Mwau, Duncan Thomas, Kala Vairavamoorthy, and Michael Westphal.

We are grateful to Lael Giebel, Emily Matthews, and Lauri Scherer for their editorial support. We are thankful to Zezhou Cai and Khyati Rathore for help with research assistance and data management, respectively. Valeria Gelman, Maria Hart, Caroline Stokes, and Adna Karabegovic kept the work moving forward. We thank our communications team, including Tini Tran, Craig Brownstein, Schuyler Null, Talia Rubnitz, and Hillary Smith who helped with messaging and outreach, as well as Romain Warnault, Carni Klirs, and Julie Moretti for their work on the graphics and layout.

We express our sincere gratitude to the Bill and Melinda Gates Foundation for funding this research. We are thankful to the UK Department for International Development (DFID) for funding this work and acknowledge the support of our institutional strategic partners who provide core funding to the World Resources Institute (WRI): the Netherlands Ministry of Foreign Affairs, the Royal Danish Ministry of Foreign Affairs, and the Swedish International Development Cooperation.

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This is the eighth thematic paper in a series of working papers that comprise the World Resources Report (WRR), *Towards a More Equal City*. To obtain an electronic copy of this paper, and/or other working papers, and to view supporting materials, please visit www.citiesforall.org.

FUNDERS

We deeply appreciate the following donors for their generous financial support:

Bill & Melinda Gates Foundation
United Kingdom Department for International Development
Stephen M. Ross Philanthropies
Denmark Ministry of Foreign Affairs
Ireland Department of Foreign Affairs and Trade
Netherlands Ministry of Foreign Affairs
Swedish International Development Cooperation Agency
United Nations Development Programme

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