Chapter 5

# Towards Sustainable Sanitation in an Urbanising World

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Additional information is available at the end of the chapter

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**Abstract**

Urban sanitation in low- and middle-income countries is at an inflection point. It is increasingly acknowledged that conventional sewer-based sanitation cannot be the only solution for expanding urban areas. There are other objective reasons apart from the lack of capital. The lack of stable energy supplies, of spare parts and of human resources for reliable operation, and the increasing water scarcity are factors that seriously limit the expansion of centralised systems. This chapter argues that a new paradigm for urban sanitation is possible, if the heterogeneity within developing cities is reflected in the implementation of different sanitation systems, adapted to each urban context and integrated under one institutional roof. This new paradigm entails: (1) innovative management arrangements; (2) increased participation and the integration of individual, community and private sector initiatives; (3) thinking at scale to open new opportunities; (4) improved analysis of the situation and awareness raising. Moving beyond conventional approaches towards sustainable urbanisation needs to follow both a top-down and a bottom-up approach, with proper incentives and a variety of sanitation systems which, in a future perspective, will become part of the 'urban ecosystem'.

**Keywords:** urban sanitation, sanitation planning, decentralised sanitation, wastewater management, faecal sludge management

## 1. Introduction

The world is experiencing unprecedented urban population growth rates, and most of this growth is projected to take place in cities of low- and middle-income countries in Africa and Asia. The United Nation's latest global population estimates, published in early 2015, project

that the global population in 2100 will be 11.2 billion. It is estimated that Africa will have 39% of the world's population, almost as much as is estimated for Asia [1].

The rapidly urbanising societies of Africa, Asia and Latin America are constricted by a quadruple challenge: urban environmental degradation, global climate change with accentuating water stress, infrastructure deficits and fast expanding peri-urban areas and informal settlements. As pointed out by [2], even when urban sanitation management infrastructure is available, it often serves only a small percentage of the urban population. Small- and medium-sized towns (<500,000 inhabitants) will carry the brunt of future urbanisation in low- and middle-income countries and will have a pronounced backlog in urban sanitation infrastructure. A recent infrastructure study of the World Bank highlighted the low access to improved sanitation in urban Africa with 51% of the population relying on traditional (unimproved) latrines, 14% on improved latrines and only 25% connected to sewers or a septic tank [3].

Urban sanitation is at an inflection point. The international community and national governments are increasingly acknowledging that conventional sewer-based sanitation cannot be the solution for all the different urban areas. Apart from the lack of capital, there are other good objective reasons why conventional urban water management does not offer the only solution for the rapidly growing cities in Asia and Africa: the lack of stable energy supplies, of spare parts and of human resources for reliable operation are factors that limit the expansion of centralised systems. In an increasing number of cities, water scarcity is also becoming an important bottleneck. As a special case, the improvement of sanitation conditions in informal settlements in low- and middle-income countries has proven difficult due to disabling institutional environments, as well as the lack of secure tenure and of the rule of law, often preventing the development of innovative management schemes. Today, a majority of urban citizens rely on on-site systems, such as septic tanks, pit latrines or cesspits. With sewer-based systems out of reach for a large part of the global population, there is an urgent need to develop more cost-effective and resource-efficient systems that can deliver the desired water services necessary for public health, protection against flooding, and the preservation of natural resources. In this chapter, we present the main reasons for environmental sanitation deficits and lay out arguments for a holistic sectoral approach that is inclusive and that incorporates innovative management arrangements for growing urban areas.

## 2. Different urban contexts—different sanitation challenges

Cities are not homogeneous, especially in low- and middle-income countries. Lüthi et al. [4] identified four typical urban contexts: (1) inner-city middle and high-income settlements, (2) planned urban development areas, (3) informal settlements and (4) peri-urban interface (see **Figure 1**). Contrasts between these contexts can be striking, that is skyscrapers and slum pockets in India or favelas next to villas with swimming pools in Brazil. It is currently common to find modern city centres next to informal neighbourhoods that lack the most basic services. The tendency in current urbanisation is an increase in segregation, with a densification and sprawling of informal settlements on the one side, and the rapid extension of medium density

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planned urban development areas, that is large fully fledged new neighbourhoods or gated communities for the middle and upper classes, on the other.

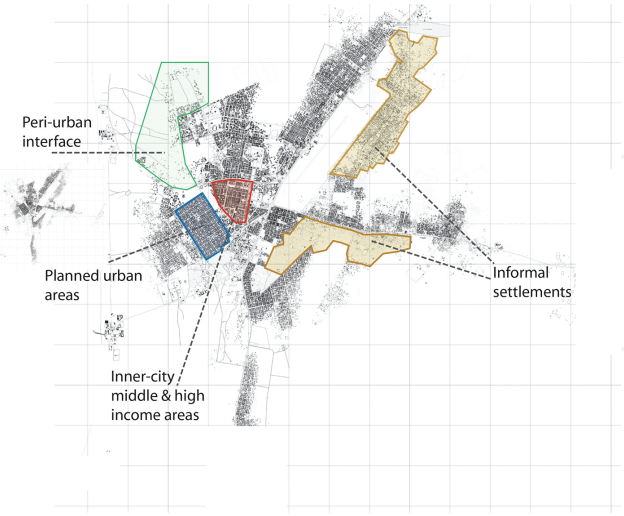


**Figure 1.** Main settlement contexts that need to be addressed in urban sanitation in low- and middle-income countries (Source: [4], p. 79).

Inner-city middle- and high-income settlements, as well as planned urban development areas, are usually characterised as having conventional centralised water supply and sewer system schemes managed by governmental institutions, typically a utility. Informal settlements and the peri-urban interface, however, often rely on on-site sanitation systems, from basic pit latrines to flush toilets with septic tanks, and sometimes on water kiosks or water trucks for their water supply. These so-called 'off-the-grid' solutions are often not managed by the government, but by self-organised private stakeholders, community-based organisations or NGOs.

The characteristics of low-income settlements make the provision of basic services intrinsically very difficult and, therefore, conventional service delivery approaches are often not viable [5]. For instance, slums are often located in areas with specific physical constraints, such as low-lying ground, steep slopes or densely packed housing with very poor access via narrow and irregular pathways. When settlements are informal, key sanitation stakeholders are reluctant to invest: governmental agencies, because such area is not formal and thus not recognised; landlords, because they often do not live there; and tenants, because they are afraid of gentrification and do not want to invest without having security of tenure. This usually results in the inhabitants of such neighbourhoods paying much more for water and sanitation than people served by the government, and the services that are provided often threaten public health.

Providing sanitation services to a city as a whole invariably requires a mixture of sanitation systems, which are appropriate for different parts of the city and which can be implemented at different scales [5]. It is unlikely that the same model of service delivery will be appropriate for all areas. Therefore, a citywide sanitation plan is likely to consist of several components designed to meet the specific physical, socio-economic and service conditions for different parts of the city. The city is characterised into sanitation zones or clusters based on such aspects as topography, population density, user preferences, affordability, existing systems and/or water availability, taking into account both the existing situation and expected changes due to urbanisation. This helps to determine where on-site or off-site, networked or non-networked, dry or wet systems are most appropriate in the short- and long term.

## 3. Sewered or non-sewered: various sanitation systems

The previous section highlights urban diversity and the related heterogeneity in terms of sanitation status. Different contexts mean different sanitation systems, therefore it is important to adopt a sanitation system approach, as illustrated by [6]. Sanitation cannot be reduced to latrines or sewers but needs to be considered as a whole value chain, consisting of a user interface (the toilet), collection/storage (e.g. pits and septic tanks), conveyance (e.g. sewers or vacuum trucks), treatment and use and/or disposal. In particular, systems can be categorised as sewered or non-sewered, as well as dry or wet (without or with water). They can also be differentiated through their scale/domain of application: on-site (for households or buildings), small-scale (for cluster of houses or neighbourhoods) or large-scale (centralised at city level). Urban centres and western cities are usually served by a single-sewer network that conveys the wastewater to a treatment plant; we will refer to this type of system in this chapter as the 'conventional system'. However, most cities around the world still rely mainly on on-site systems, where domestic wastewater accumulates in pits and tanks in a form called 'faecal sludge' or 'septage'. Now and then, this faecal sludge needs to be pumped and transported to a faecal sludge treatment plant.

It is clear that it will not be possible to connect all urban areas to a conventional system in the foreseeable future. Nor is it desirable. The main bottleneck is of course financial: the amount of money needed to provide this is immense, and most governments do not have enough funds to build such infrastructure; besides, when such an infrastructure exists, the risk of failure is high when there is no financial means and capacities to operate and maintain the system properly. The further one is from the city centre, the more expensive it also gets. The economies of scale that can be achieved at the treatment plant level are outweighed by the dis-economies of scale of the sewer network [7]. Low-density peri-urban areas especially have a very high cost per capita. Sometimes, the geography and population density of the city make a conventional system simply unrealistic, such as in Durban, South Africa, which is characterised by low density and a hilly topography. Other cities such as Dakar, Senegal, fully assume faecal sludge management (FSM) as part of its sanitation system in its own right, cohabiting with sewers. By accepting this and by investing in FSM, the utility ends up treating a lesser volume of wastewater per capita, while avoiding the massive investments required to provide a sewer

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connection to all. It is the role of a good master planning exercise to determine which areas are best connected to sewers and which can be best served by FSM.

Besides the crucial system choice, there is also the choice of scale. This results from the comparison of both the costs involved, on a life-cycle basis, and the associated management schemes. For both sewered and unsewered systems, there are viable alternatives at different scales, from city to neighbourhood and the individual building level. Small-scale sanitation systems or 'decentralised systems' are seen as a promising alternative for some selected urban areas. They offer the opportunity to implement new management schemes and go beyond some of the current sanitation bottlenecks.

Total sewerage coverage may also not be desirable in cities that are water scarce. In such circumstances, it does not make sense to use large amounts of drinking water simply to flush excreta and to keep the sewer system running. Besides the current threat of water scarcity to our societies, there is also the forecasted lack of nutrients for agriculture, especially for phosphorus. While phosphorus and nitrogen are now considered treatment priorities for Western governments as they may lead to eutrophication problems in natural water bodies, they are also essential for food safety. Since these nutrients are located in urine and excreta, the sound management of resources advocates for source separation to avoid diluting them in large amounts of water, which renders their recovery or treatment both cumbersome and expensive. Source separation or even on-site treatment could offer major advantages for future sustainable urban water-management systems [8].

The following sections cover the current bottlenecks for the fast increase in sanitation coverage and how innovative sanitation planning and management can contribute to the development of more sustainable sanitation systems that are contextual, integrative and inclusive.

## 4. Current sanitation backlog and bottlenecks

While development priorities shift from the millennium development goals (MDGs) to the sustainable development goals (SDGs), it has to be recognised that few low- and middle-income countries were even close to reaching their sanitation MDGs. In many of them, demographic growth outweighed the progress made, despite the billions of dollars poured into the sector. A lot of infrastructure is not adapted to the context and/or not sustainable, thus failing to serve the population properly in the long run. Besides, the conventional approaches fail to reach large (and often most) parts of the population. The dearth of pragmatic answers to the need for quick increases in sanitation coverage is mainly due to the lack of an enabling environment to develop solutions that move away from the conventional system. Lüthi et al. [9] structure the enabling environment in six categories: (i) government support; (ii) legal and regulatory framework; (iii) institutional arrangements; (iv) skills and capacity; (v) financial arrangements; and (vi) socio-cultural acceptance. In the past, many water and sanitation projects failed because of the lack of an integrated approach. Sanitation programmes should take these six dimensions into consideration to ensure the long-term sustainability of sanitation infrastructure and services.

The major barriers to progress in sanitation coverage lie within the institutions, policies and realities of low- and middle-income countries [2]. The public sector is often weak in terms of skills, structures, planning capacity and bureaucratic procedures, and mechanisms are not always in place to recover investment, operation or management costs, leading to the degradation of service provision or even system failure. Depending on the political structure of the city, the division of responsibilities relating to sanitation can be an institutional headache. Responsibilities for sanitation service provision are often fragmented and sometimes overlapping among different departments and ministries. This fragmentation and overall 'poor' urban governance make coordinated action difficult and can even lead to conflict between stakeholders for resources and areas of influence.

For example, some reasons why faecal sludge management systems have not been widely implemented are the financial and political complexity involved, as well as the overlapping and unclear allocation of responsibilities and a lack of incentives for efficient operation [10, 11]. This is due to the number of stakeholders who have a financial interest in the system and also to the diversity of interests of each stakeholder. Unlike other types of infrastructure (e.g. electricity) where a single utility is usually responsible for generation, delivery, operation, maintenance and billing, a faecal sludge system is more commonly a collection of stakeholders, each of whom is responsible for a different part of the treatment chain. Dysfunctional institutional frameworks result in both a lack of accountability and disagreements between stakeholders, which can even sometimes lead to sector blockage.

The situation is similar with small-scale and on-site systems: such systems often show a mismatch with many institutional conditions (regulations, professional codes or user expectations) [12]. Many factors have been put forward to explain that conventional sewerage remains the predominant paradigm for urban sanitation delivery. There is, however, little hard evidence to say whether this is mostly due to bureaucratic or technical inertia, risk aversion, corruption (and, hence, the preference for high-cost schemes with limited local accountability), political expediency (the need to be seen to be doing something), the perception that only these systems are 'modern', or simply a lack of knowledge [13]. What is clear is that whatever incentives currently exist tend to encourage local and central authorities and their advisors to stick to conventional top-down planning and conventional centralised sewerage schemes.

Moving beyond conventional approaches towards sustainable urbanisation needs to be both top-down and bottom-up. Top-down, because it is often the only way to reform institutions, laws and regulations and bottom-up, because little can be done without dynamic individuals, communities and private sector stakeholders who have the energy, vision and creativity to innovate and validate new approaches. Flexibility is needed from governments to integrate non-governmental initiatives in their planning and to allow them to be replicated and scaled up. Above all, developing the right incentives to let initiatives grow and prevent them from being stopped by the established bureaucracy is essential.

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## 5. The new paradigm: integration of several sanitation systems under one roof

Moving beyond business as usual necessitates leadership, vision and building partnerships. The sanitation sector is, and will remain for decades to come, under the overarching responsibility of the public sector. What can be changed is the mode of operation, adapting it to multi-stakeholder settings and fostering enabling environments. The new paradigm, which is advocated in this chapter, could materialise along different axes:

1. Building interfaces: integrated and inclusive planning implies the development of interfaces between the different sanitation systems in order to create synergies and bring them under one roof. This requires innovative management and financial schemes.
2. Participation: while conventional sewer-based system are mostly planned and implemented by a top-down approach, this is not the case with faecal sludge management or neighbourhood-level systems, where the government and utility are not the only ones to run the show. Here, the role of individuals, communities and the private sector are essential for sustainability.
3. Large-scale vision: planning for sustainable sanitation alternatives means thinking at scale from the outset with an incremental approach. Many projects fail because they remain at pilot scale and cannot reach the economies of scale necessary for their survival or replication.
4. Communication: focus on state-of-the-art data collection, analysis and communication in order to allow urban leaders and sanitation stakeholders make informed decisions.

Innovative management schemes need to provide the incentives required by urban sanitation stakeholders to change their mode of operation if the conventional paradigm of top-down planning and conventional centralised sewerage is to be challenged [13].

### 5.1. Towards innovative management arrangements

Proper management is above all a matter of setting the right incentives and ensuring financial sustainability. In the current situation, many governmental schemes do not provide the incentives or the financial resources for sanitation systems to be run properly, and a fortiori to be extended to low-income areas. One way of responding to this mismatch in incentives is to unbundle urban sanitation vertically and horizontally [13]. The horizontal unbundling characterises the implementation of different systems for different urban areas, as described earlier. This is a departure from one-size-fits-all solutions and allows for the use of least-cost solutions because it enables the deployment of both on-site and off-site systems in areas, depending on housing density, ground conditions, tenure and a range of other factors. Vertical unbundling recognises that communities or private sector stakeholders may be willing and able to take responsibility for part of the sanitation supply chain. Both vertical and horizontal unbundlings tend to promote decentralisation.

The result of conceptually dividing a city into management units depending on both incentives and technical feasibility is that many elements of the system can then be developed independently [13]. Community initiatives can become less dependent on city-wide actions, and financing for small elements of the system may be easier to mobilise. These reconfigurations, therefore, allow for incremental development. Notwithstanding, whatever level of delegated or decentralised management is chosen, overall government supervision is needed with proper management interfaces.

*5.1.1. Management interfaces*

While vertical and horizontal unbundling offer increased flexibility, they also require skilled coordination [13]. Communities or informal private stakeholders can rarely manage the whole sanitation supply chain. For example, communities may be willing to invest in a sewer network, but rarely in a treatment plant; they also often do not have the skills or the willingness to commit sufficient financial resources to build a state-of-the-art sewer network. This may result in dysfunctional networks, which in the end cannot be connected to a small-scale treatment plant, or to the city sewer system.

The creation of well-designed management interfaces is, therefore, key for sustainable urbanisation. The scaling up of small-scale wastewater treatment systems necessitates good coordination at the state/city level. Indonesia integrated community-based decentralised wastewater systems into its sanitation policy, which resulted in the implementation of thousands of systems. However, it turned out that communities alone cannot manage the treatment plants in the long run. There is a necessity for a higher structure, a 'centralised management of decentralised schemes' to carry out the minimum operation and maintenance required, to monitor the effluent quality and to take care of major troubleshooting. Scaling up entails more than replicating a large number of discrete projects [14].

Coordination is also necessary for faecal sludge management. In most cities in low- and middle-countries, there is a thriving private sector around faecal sludge/septage emptying. Unfortunately, without coordination at the city level and faecal sludge treatment infrastructure, most of the sludge ends up being discharged directly into the environment.

In Dakar, Senegal, the utility (ONAS) built faecal sludge treatment plants and integrated the faecal sludge emptying sector (privately owned vacuum trucks) into its scheme. It turned out to be a win-win situation, as the private service providers desperately needed locations to safely discharge sludge within the city. ONAS further improved the quality of the service with the creation of a call centre. This optimised the distances that the private service providers have to drive and, as a consequence, decreased the emptying fee, thus making it more affordable—a sort of 'Uber' for sludge collection.

Small-scale sanitation systems, unfortunately, still lack good examples of centralised management in low- and middle-income countries. A clear competitive advantage of most small-scale sanitation systems is that they do not require permanent staff on-site, except, perhaps, for a community member to run the pumps. Therefore, a centralised management unit at the city level, embedded within the utility, would consist of a few skilled staff, specially trained to

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operate small-scale systems. Such a unit would be in charge of monthly monitoring and troubleshooting, whereas the sewer network and routine maintenance (such as cleaning) would be delegated to community or neighbourhood members. Both could be connected via a call centre in case of problems. Recent technological advances in fields, such as mobile communication, chemical sensors and remote control, open up a broad and promising range of new system configurations [15].

### *5.1.2. Delegated management*

Servicing low income and informal settlements remains a big challenge. Delegating service provision to local operators, including private companies, NGOs, CBOs, User Associations or Water Trusts is one solution for the utility to help service these areas [11, 16]. It is an effective approach, but a number of barriers must be overcome, especially technical and financial capacities and access to credit. Above all, delegated management models need to be based on clearly defined contracts which ensure benefits to all parties (consumer, local operator, utility) [16]. The utility takes on the role of a controller, setting standards and monitoring the service delivery.

**Case study: Delegated management in Lusaka, Zambia**

In Lusaka, Zambia, the commercial utility, the Lusaka Water and Sewerage Company (LSWC), has the mandate for water supply and sewerage delivery for the whole city. Since LWSC, however, was not serving informal peri-urban areas, two community-based Water Trusts were established by the NGO CARE to fill the gap in service delivery in Kanyama and Chazanga, two of the biggest peri-urban areas of the city. LWSC decided to integrate this initiative in its water supply service delivery scheme and formally delegated the management of the water supply in these neighbourhoods to the Water Trusts through the provision of a license. LWSC later also recognised that the conventional sewer system approach they followed in the city centre would not work in the peri-urban areas where the Trusts are working and decided to also delegate sanitation service provision to the latter. A latrine emptying service was established for the two neighbourhoods by formalising the status of informal manual emptiers already working there. These workers collect faecal sludge from pit latrines and bring it to a treatment plant. The long-term goal was for them to work as proper private entrepreneurs [17].

The Water Trusts are successfully delivering water and sanitation services due to several reasons: (i) services are adapted to the local conditions; (ii) they are well positioned and known within the community, have local staff and offices, and are therefore easily accessible; and (iii) they can support the latrine emptiers with their management capacities [18].

In the meanwhile, LWSC further recognised that the different conditions in low-income peri-urban neighbourhoods require different management schemes within their organisation and, therefore, established a department for peri-urban affairs, consisting mostly of social workers. This department is taking the lead in the coordination of these innovative delegated management schemes.

Following the example of several European countries such as Germany or France, which established decentralised management schemes in rural communities, collaborative arrangements should be sought for. A management interface also means the creation of operator networks, joint capacity building and cooperation between communities and neighbourhoods. This results in an increase in capacities and efficiency, as well as a higher level of professionalism.

*5.1.3. Inclusive stakeholder involvement*

Innovative management arrangements imply the involvement of stakeholders beyond the utility in the planning, implementation and operation of sanitation systems. In faecal sludge management for example, the involvement of the private—and sometimes informal—service providers is crucial; for small-scale sanitation systems at neighbourhood level, the involvement of the community is not less important. Engagement with different stakeholder groups is a critical activity that is essential for the successful development of sustainable sanitation services and behaviour change [5, 9, 19]. Enabling the civil sector and the local private sector to take a more proactive role in the definition, selection, planning and eventually management of appropriate and locally contextualised services is seen as the way forward for sustainable urban sanitation.

Stakeholder involvement in the water and sanitation sector is justified by four main arguments: ownership, efficiency, better design and empowerment. Stakeholder involvement is the art of including stakeholders in the urban planning process in order to take into account their needs, priorities and interests, to achieve consensus and to remove opposition; in other words, to make them participate. It is largely about defining the participation level of people in the process, from simple information to consultation, collaboration or delegation, and how to best answer their needs, for example through awareness raising or training and capacity building.

The benefits of alternative sanitation systems may not be clear to everybody from the beginning and some people may be reluctant to change their daily routine. For these reasons, information and transparency are fundamental. Involvement is also about showing the benefits of change to the different stakeholders and giving incentives. For example, with proper FSM, authorities gain recognition by improving the population's welfare. Informal service providers may get a voice, a status and get out of the margins of society, while the service they provide gets widely recognised. Private collection and transport entrepreneurs gain formal disposal sites and the price of services may be reduced for the households [20].

The capacity to provide services effectively and efficiently is the backbone of sustainable service provision. This includes well-trained engineers and planners at all levels (municipal, provincial and central government), but also private sector and NGO stakeholders who have their role to play. That is why capacity building and on-the-job training are crucial to improve service delivery and expand coverage in rapidly urbanising areas. The necessary capacity will need to be developed at both, the individual and collective level; individual capacity refers to particular skills that individual people have and collective capacity refers to a community or a group's capacity to organise, mobilise and support collective actions [21]. Important components of water and sanitation sector capacity building involve (i) strengthening and

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improving management in terms of building technical, financial and managerial capabilities; (ii) upgrading institutional and technical capacities of the key actors to help identify, understand and evaluate complex urban environmental problems; (iii) establishing co-operative partnerships with government, elected and official, civil society organisations, and the private sector to deal with cross-cutting challenges; (iv) utilising participatory tools in planning, decision-making, and political processes which facilitate the development of a common vision, articulation of needs and joint action [22].

### 5.2. Thinking at scale

To solve the sanitation issue in an urbanising world, decision-makers need to think at scale. Isolated initiatives carried out by dynamic entrepreneurs and civic champions are not the answer to immense sector challenges. 'Pilots never fail, but pilots never scale' (Gebauer, personal communication). Two main reasons can be mentioned for that [23]: (i) there is a tendency to overinvest in pilots in order to ensure their success, which per se makes them non-replicable; and (ii) pilots cannot reach the economies of scale which would make them competitive and sustainable, both in terms of implementation and management.

Thinking at scale is necessary to establish crucial elements, such as centralised management units or call centres. The gains driven by city-level management of FSM can be reinforced by the optimal localisation of the faecal sludge treatment plant(s), minimising the distances travelled from each neighbourhood. The centralised management of decentralised systems can only be achieved when reaching numbers from the beginning, that is starting with a critical mass of projects.

Thinking at scale allows for the development of more sustainable management schemes, which also provide incentives for the private sector. It permits the standardisation of sanitation systems, as well as the development by the government of such mechanisms as licenses and certifications, and it helps to attract investors. Indeed, many promising small-scale initiatives are not replicated because the capital needed is too low to interest the main urban sanitation donors, who are used to multi-million dollar programmes. In general, access to small amounts of credit is often a major bottleneck to sanitation stakeholders [13] and micro-entrepreneurs. In Dakar, for example, a special credit line was opened to allow faecal sludge service providers to borrow the amounts needed to renew their truck fleets.

#### *5.2.1. Towards sustainable business models for innovative sanitation services*

Some sanitation systems can constitutes an innovation in a specific context. As such, in order to be able to reach scale, new markets need to be created, highlighting the potential for the private sector and job creation. As pointed out by Truffer et al. [12], on-site treatment systems represent a major challenge to the current competencies of utilities in terms of their providing urban water management services and organising their value chain. A future large-scale application, thus, depends on the successful organisation of innovation processes in three domains [12]: (i) technological components and system integration, (ii) value chain formation

and the development of new business models, and (iii) institutional innovations to create appropriate conditions under which these systems can reliably operate.

In order to reach the base of the pyramid (BoP), that is the low-income customers, innovative business models must be defined. Key factors for success are affordability, accessibility, acceptance and awareness [24]. Unfairly, low-income inhabitants in situations without proper service often have to pay more for water and sanitation than people connected to the governmental sewer system. Reasons for this are the lack of accessibility to services, transport costs, lack of economies of scale and the fact that sometimes illicit operators take advantage of the absence of viable public services. It, however, shows that there is a capacity-to-pay even in low-income neighbourhoods.

In such neighbourhoods, the sanitation challenge often starts with the lack of toilets at the household level. People have to resort to poorly maintained public toilets, shared toilets or in the worst case to open defecation. Sanitation improvements cannot be reached with the construction of new toilets only; what is needed is the development of an integrated service chain that can maintain the toilets and collect, transport and treat the excreta. In Nairobi, Kenya, the NGO Sanergy developed a system based on the use of public toilets where urine and faeces are collected in separate containers and transported to a treatment plant where they are turned into fertilisers. The service is based on a franchising system in which micro-entrepreneurs (the franchisees) decide to maintain a toilet, versus a small fee from the users. Therefore, it includes local residents and offers job creation on-site.

In Manila, Philippines, the Manila Water Company managed to incrementally extend the coverage of desludging at the household level by restructuring the tariff system. Desludging costs for households was fixed to the water volume used and not per trip as is usually the case. The tariff system created access for poor people to the desludging services, as they use less water volume. In Bangalore, this increase was triggered by the private sector itself. These businesses emerged when the Indian government was sponsoring the setting-up of toilets with pit latrines. What the Indian government did not regulate was the emptying of the pits. Some smart entrepreneurs recognised this lack of regulation and started the so-called 'honey-sucker' desludging micro-businesses (one entrepreneur, one driver and one helper). Interestingly, the micro-businesses themselves did not grow, but were replicated to more than 300 businesses. Through collective action, the micro-honey-sucker businesses developed a specific vacuum truck, which drove cost reduction from 10 to 1, customised a specific pump, and developed pricing mechanisms for apartment buildings [25, 26]. They also developed agreements with farmers to get the sludge composted and reused. In short, through their entrepreneurial approach, they created their own market and business model.

*5.2.2. Centralised vs. decentralised, or how to tackle the uncertainty of urban growth*

Some of the most significant advantages of decentralised sanitation systems are their flexibility, modularity and cost-effectiveness [27, 28]. They can be implemented in stages and built as close as possible to the actual wastewater volume, reducing the possibility of accruing idle capacity costs [29].

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The high uncertainty in city developments and population growth in low- and middle-income countries can be addressed through a modular and incremental approach. Instead of investing large sums for treatment plant designed for a planning horizon of 30 years, several smaller plants can be built with a planning horizon of 15 years, thus serving more people in the short-term. Such an approach allows for adaptation to better meet the rise in demand, and for the avoidance of costly over-capacities. The optimal level of decentralisation must be carefully analysed for a cost-effective clustering of the city. Overall, uncertain urban growth advocates for further decentralisation of sanitation services in the decades to come.

As mentioned earlier, both vertical and horizontal unbundling tend to promote decentralisation. If wastewater treatment plants usually offer economies of scale (the bigger the plant, the lower the price per capita), it is not the case for sewer networks, which typically represent more than 80% of the investment costs of a sanitation system [30], and also a significant part of the operation costs. The predominant 'expand and upgrade' leads to biased economic incentives because stakeholders tend to base their decisions on economies of scale in the cost of a centralised wastewater plant, while neglecting economies of scale at the level of the entire network, which are, as a rule, much more difficult to assess [31]. The optimum configuration will generally be defined by some sort of hybrid constellation [32], also referred to as a distributed wastewater infrastructure [33]. The strong reliance of most utility services on centralised network infrastructure is also becoming increasingly challenged by new technological advances in decentralised alternatives, as well as remote operations [28]. Eggimann et al. [34] confirmed that the optimal degree of centralisation decreases with increasing terrain complexity and settlement dispersion, while showing that the effect of the latter exceeds that of topography. The use of more decentralised sewer systems or even simplified sewer systems can allow for major savings, by reducing the number of pumps and force mains, the depth of sewers and the size of manholes and the gradient of the pipes [6]. Overall, it also drastically reduces the operation costs. In case of organised communities, such sewer systems can be partly built and managed by the community itself.

### 5.3. Communication: understanding and visualising the situation

A clear overview of the diverse sanitation challenges in a city is the basis for the development of sound urban sanitation strategies. This requires good quality data and awareness from the decision makers. Accessing relevant data is challenging, especially in contexts where data is scarce and the urban development very dynamic. Often, data are either not collected or analysed properly, or, sometimes, hidden or manipulated for political or personal reasons. Governmental agencies usually have some reports, statistics and maps that can serve as a preliminary introduction. However, they should always be considered with care and, therefore, the collection of primary data is recommended. In unplanned and informal neighbourhoods without legal status, there is often no official data and the collection of primary data can be the only way of assessing the urban environment. The best way to get a reasonably accurate estimation is to rely on several sources of information, which can be cross-checked and, if needed, complemented by further research [35].

All relevant urban sanitation stakeholders should be consulted in the planning process, such as water and sewerage utilities, the private service providers and the end-users. This helps the understanding of the heterogeneous urban environment and gives access to first-hand information from different perspectives. Depending on the stakeholder, data can be collected through different tools, such as household surveys and expert interviews, as well as other participatory methods that are focus group discussions, town hall meetings, transect walks or participatory mapping [5, 9].

New technologies facilitate data collection and visualisation. Mobile data collection and geo-referencing tools quicken the process, increase the quality of the data collected and allow rapid visualisation of complex urban areas. Mobile data collection is gaining importance as data can be collected with any mobile phone and viewed in real time [36]. With the decreasing costs and complexity of geospatial data collected from satellites, these data become accessible not only to all urban planners but also to civil society, which can even participate in the monitoring efforts. This is often already done, for instance, with the monitoring of water points.

An innovative way to visualise outcomes and communicate the urban sanitation challenge at the city-wide level are the so-called 'shit/excreta flow diagrams' (SFDs), which clearly show how excreta is or is not contained as it moves along multiple pathways from defecation to disposal or end-user. As illustrated in **Figure 2** for the city of Dar es Salaam, Tanzania, the SFD

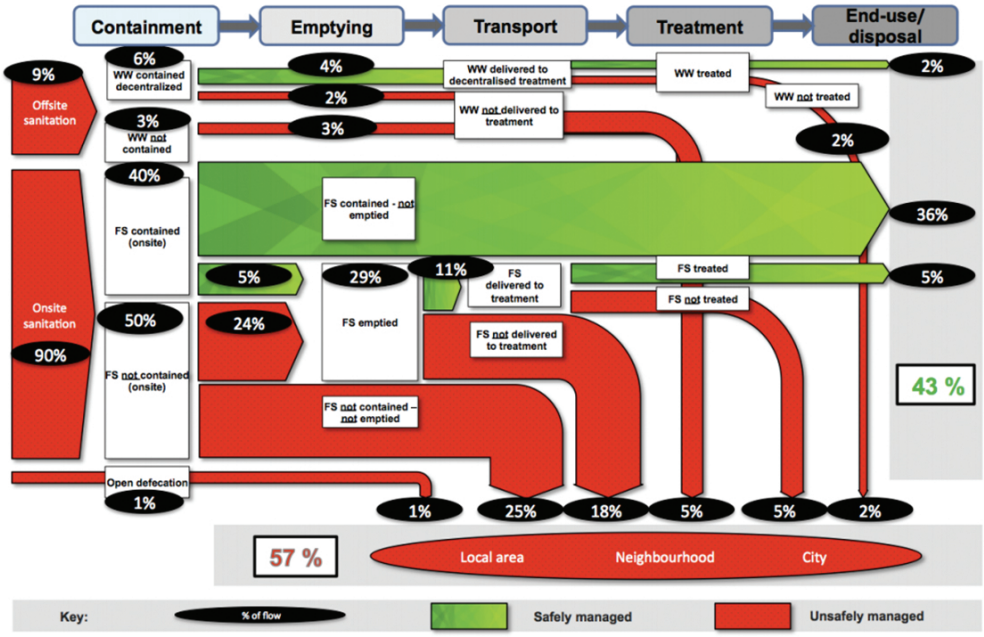


**Figure 2.** The excreta flow diagram for Dar Es Salaam, Tanzania, shows the proportion of faecal matter that is safely managed (in green) compared to unsafely managed streams (in red) [37].

http://dx.doi.org/10.5772/63726

is an advocacy and decision-support tool that can easily be understood by non-technical key stakeholders and by civil society. It, therefore, has the potential to shift the focus of attention, money and activities towards more effective and inclusive urban sanitation beyond water-borne sewerage.

## 6. Sanitation in the urban ecosystem

Integrating sanitation in the urban ecosystem, that is seeing it as more than merely collecting and treating wastewater, is seen as a main driver or incentive for more efficient and sustainable sanitation services. This can take different forms: (i) synergies between different services (e.g. energy, communication); (ii) multi-functional sanitation concepts; (iii) urban valorisation of sanitation end products (e.g. treated wastewater, nutrients, heat or biogas).

Good city sanitation plans recognise the links between sanitation and other municipal services [5]. For example, uncollected solid waste ends up in drains and sewers, greatly increasing maintenance requirements. Consideration of the integration between these different services is important to ensure effective sanitation service delivery. Storm water drainage also needs to be planned in parallel, as neglecting it can quickly lead to the collapse of the sanitation system, especially combined with the lack of solid waste management.

A utility which manages different urban services may be more sustainable if one of these public services is lucrative. For example, in Cuenca, Ecuador, the utility manages water, sanitation and communication. In that case, the communication sector contributed to the development of inclusive and state-of-the art sanitation services, through cross-financing. This would not have been possible if both services were managed separately. Managing several services at the same time can also support the often delicate issue of fee collection. For example, collecting sanitation fees together with the electricity bill can significantly increase the collection rate, and thus the cost recovery.

Similarly, multi-functional sanitation concepts increase the sustainability of the sanitation component through the provision of other services. Multi-functional public toilet concepts in low-income settlements have made their proof, like the Ikotoilet in Kenya, which brings together toilets, showers, sale of personal care products and, in collaboration with local companies, supports advertising, telephony, and shoe-polishing services as well as sales of snacks, drinks and newspapers. In general, linking productive assets with sanitation services increases sustainability. Activities needing biogas, such as communal kitchens, can for instance be built in synergy with sanitation infrastructure in green markets; similarly, decentralised treatment plants can be built so that the treated effluent can directly be used by urban farmers for irrigation. Linked with solid waste management and landscaping, multi-functional sanitation concepts can also contribute to increase the recreational value of a neighbourhood.

The valorisation of sanitation end products should be fostered. In high-income countries, grey water recycling in buildings, on-site reuse of treated wastewater for urban gardening and heat recovery from sewage are increasingly being implemented, as well as the biogas production

in centralised treatment plants for electricity production or as a fuel for public transportation. Technological advances, increasing scarcity of water and rising prices of fuel and fertilisers will soon make such techniques more affordable and competitive in low- and middle-income areas as well.

## 7. Conclusion

Urban sanitation is at an inflection point: although conventional sewer systems and large-scale treatment plants are still seen as the golden standard, there is an increasing acknowledgement that sanitation systems such as faecal sludge management or decentralised/small-scale systems are complementary options and constitute viable alternatives in the long run for selected parts of cities. The change in thinking, however, still has to reach all the city sanitation stakeholders to become a widespread and operating reality, from the urban leaders to the service providers and the engineers and consultants. The multi-disciplinary nature of the new approaches makes them more complex than the engineering-centric one. In order to reach full sanitation coverage in low-and middle-income countries, the sector should be enriched with the social and economic skills that are needed to involve the different sanitation stakeholders in planning processes and devise innovative management and financial schemes.

Although going beyond the current bottlenecks may seem daunting, it is possible to change the situation by creating the right incentives for the different stakeholders. The new paradigm advocated for in this chapter is in line with that: building interfaces, delegating management through arrangements which ensure benefits for all parties, increasing participation, thinking at scale and fostering better communication all contribute to reducing the sanitation burden of the governmental institutions and improving decision making, while increasing sanitation coverage and thus the consumer basis. There are ways to structure the sector through better governance, appropriate planning tools, the involvement of private stakeholders and innovative financing mechanisms.

Sanitation has a key role to play in sustainable urbanisation, and it needs to be fully integrated in the current thinking about 'circular,' 'efficient,' 'green' or 'water-secure' cities. Sanitation, as the supply chain for both used water and nutrients, is at the core of these urban sustainability concepts. Cities of the future will probably treat wastewater and sludge as close as possible to their source, to enable on-site reuse of resources. Many pilot projects already go in this direction, by fostering grey water recycling in buildings and use of treated wastewater in urban gardening. In water-scarce regions, there is a growing concern to plan wastewater treatment infrastructure so that it can directly contribute to groundwater recharge and safe water supply.

Integrating several sanitation systems under one roof, as has been outlined in this chapter is a first necessary step for successful sanitation coverage in rapidly urbanising cities. The better integration of sanitation in the 'urban ecosystem' is the promising second step, contributing to two of the main drivers of change: reducing the costs through better synergies among services, while providing more incentives to the sanitation stakeholders.

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## References

[1] United Nations, Department of Economic and Social Affairs, Population Division (UNDESA). The World Population Prospects: 2015 Revision [Internet]. 2015. Available from:http://www.un.org/en/development/desa/publications/world-population-prospects-2015-revision.html [Accessed: 01.04.2016].

[2] Mara D, Alabaster G. A new paradigm for low-cost urban water supplies and sanitation in developing countries. Water Policy. 2008;10(2):119–129. doi:10.2166/wp.2008.034.

[3] Foster V, Briceno C. Africa's infrastructure: a time for transformation. Washington DC, US: World Bank; 2010. doi:10.1596/978-0-8213-8041-3.

[4] Lüthi C, Panesar A, Schütze T, editors. Sustainable sanitation in vities – a framework for action. 1st ed. The Netherlands: Papyroz Publishing House; 2011. 148p. doi: 10.1.1.365.6104.

[5] Parkinson J, Lüthi C, Walther D. Sanitation 21 – a planning framework for improving city-wide sanitation services. 1st ed. London, UK: IWA; 2014. 38p.

[6] Tilley E, Ulrich L, Lüthi C, Reymond P, Zurbrügg C. Compendium of sanitation systems and technologies. 2nd ed. Dübendorf, Switzerland: Eawag; 2014. 176p.

[7] Pinkham R D, Hurley E, Lovins A, Magliaro J, Watkins K. Valuing small-scale wastewater technologies: a catalog of benefits, costs, and economic analysis techniques. 1st ed. Colorado, US: Rocky Mountain Institute; 2004.Available from: http://www.rmi.org/Knowledge-Center/Library/W04-21_ValuingDecentralizedWastewater [Accessed: 18.05.2016]

[8] Larsen T A, Gujer W. Implementation of source separation and decentralization in cities. In: Larsen T A, Udert K M, Lienert J, editors. Source separation and decentralization for wastewater management. 1st ed. London, UK: IWA Publishing; 2013. p. 135–149.

[9] Lüthi C, Morel A, Tilley E, Ulrich L. Community-led urban environmental sanitation, complete guidelines for decision-makers with 30 tools. 1st ed. Dübendorf, Switzerland: Eawag; 2011. 100p.

[10] Tilley E, Dodane P. Financial transfers and responsibility in faecal sludge management chains. In: Strande L, Ronteltap M, Brdjanovic D, editors.Faecal Sludge Management. Systems Approach for Implementation and Operation. 1st ed. London, UK: IWA Publishing; 2014. p. 273–291.

[11] Bassan M. Institutional frameworks for faecal sludge management. In: Strande L, Ronteltap M, Brdjanovic D, editors. Faecal sludge management. Systems approach for implementation and operation. 1st ed. London, UK: IWA Publishing; 2014. p. 255–271.

[12] Truffer B, Binz C, Gebauer H, Störmer E. Market success of on-site treatment: a systemic innovation problem. In: Larsen T A, Udert K M, Lienert J, editors. Source separation and decentralization for wastewater management. 1st ed. London, UK: IWA Publishing; 2013. p. 209–223.

[13] Evans B. Sanitation in cities of the global south – is decentralisation a solution? In:Larsen T A, Udert K M, Lienert J, editors. Source separation and decentralization for wastewater management. 1st ed. London, UK: IWA Publishing; 2013. p. 117–131.

[14] Eales K, Siregar R, Febriani E, Blackett I. Review of community managed decentralized wastewater treatment systems in Indonesia. 1st ed. Indonesia: WSP; 2013.

[15] Olsson G. The potential of control and monitoring. In: Larsen T A, Udert K M, Lienert J, editors. Source separation and decentralization for wastewater management. 1st ed. London, UK: IWA Publishing; 2013. p. 179–191.

[16] Water & Sanitation for the Urban Poor (WSUP). The urban programming guide – how to design and implement an effective urban WASH programme. 1st ed. London, UK: WSUP; 2014. 53p.

[17] Mulenga M. Faecal sludge management by a water trust in Zambia – the case of Kanyama, Lusaka. In: FSM3; 18–22 January 2015; Hanoi, Vietnam. IWA; 2015.

[18] Water & Sanitation for the Urban Poor (WSUP). FSM services in Lusaka: moving up the excreta management ladder [Internet]. 2014 [Updated: 2014]. Available from: http://www.wsup.com/resource/fsm-services-in-lusaka-moving-up-the-excreta-management-ladder/ [Accessed: 06.04.2016].

[19] Reymond P. Planning integrated faecal sludge management systems. In: Strande L, Ronteltap M, Brdjanovic D, editors. Faecal sludge management. Systems approach for implementation and operation. 1st ed. London, UK: IWA Publising; 2014. p. 363–387.

[20] Reymond P, Bassan M. Stakeholder engagement. In: Strande L, Ronteltap M, Brdjanovic D, editors. Faecal sludge management. Systems approach for implementation and operation. 1st ed. London, UK: IWA Publishing; 2014. p. 341–362.

[21] Hamdi N, Goethert R. Action planning for cities. Community practice. 1st ed. Chichester, UK: Wiley; 1997.

[22] Markard J, Parkinson J. Putting Plans into Practice. In: Lüthi C, Panesar A, Schütze T, editors. Sustainable sanitation in cities – a framework for action. 1st ed. The Netherlands: Papyroz Publishing House; 2011. p. 148.

[23] Reymond P, Abdel Wahaab R, Moussa M. Policy recommendations for the scaling-up of small-scale sanitation in Egypt. 1st ed. Cairo, Egypt: Eawag; 2015. 40p.

[24] Anderson J, Markides C. Strategic innovation at the base of the economic pyramid. 1st ed. Germany, UK: European School of Management and Technology, Germany; London Business School, UK; 2006.

[25] Kvarnström E, Verhagen J, Nilsson M, Srikantaiah V, Ramachandran S, Singh K. The business of the honey-suckers in Bengaluru (India): the potentials and limitations of commercial faecal sludge recycling – an explorative study. 1st ed. The Hague: IRC International Water and Sanitation Centre; 2012.

[26] Hystra. Designing the next generation of sanitation businesses [Internet]. 2014 [Updated: 2014]. Available from: http://hystra.com/sanitation/ [Accessed: 06.04.2016].

[27] Massoud M A, Tarhini A, Nasr J A. Decentralized approaches to wastewater treatment and management: applicability in developing countries. Journal of Environmental Management. 2009;90(1):652–659. doi:10.1016/j.jenvman.2008.07.001.

[28] Libralato G, Volpi Ghirardini A, Avezzù F. To centralise or to decentralise: an overview of the most recent trends in wastewater treatment management. Journal of Environmental Management. 2012;94(1):61–68. doi:10.1016/j.jenvman.2011.07.010.

[29] Maurer, M. Specific net present value: an improved method for assessing modularisation costs in water services with growing demand. Water Research. 2009;43(8): 2121–2130. doi:10.1016/j.watres.2009.02.008.

[30] Maurer M, Rothenberger D, Larsen T A. Decentralised wastewater treatment technologies from a national perspective: at what cost are they competitive? Water Science and Technology: Water Supply. 2005;5(6):145–154.

[31] Maurer M, Scheidegger A, Herlyn A. Quantifying costs and lengths of urban drainage systems with a simple static sewer infrastructure model. Urban Water Journal. 2013;10(4):268–280. doi:10.1080/1573062X.2012.731072.

[32] Poustie M S, Deletic A, Brown R R, Wong T, de Haan J, Skinner R. Sustainable urban water futures in developing countries: the centralised, decentralised or hybrid dilemma. Urban Water Journal. 2015;12(7):543–558. doi:10.1080/1573062X.2014.916725.

[33] Tchobanoglous G, Leverenz H. The rationale for decentralization of wastewater infrastructure. In: Larsen T A, Udert K M, Lienert J, editors. Source separation and decentralization for wastewater management. 1st ed. London, UK: IWA Publishing; 2013. p. 101–115.

[34] Eggimann S, Truffer B, Maurer M. To connect or not to connect? Modelling the optimal degree of centralisation for wastewater infrastructures. Water Research. 2015;84(1): 218–231. doi:10.1016/j.watres.2015.07.004.

[35] Reymond P. Assessment of the initial situation. In: Strande L, Ronteltap M, Brdjanovic D, editors. Faecal sludge management. Systems approach for implementation and operation. 1st ed. London, UK: IWA Publishing; 2014. p. 295–318.

[36] Hutchings M, Dev A, Palaniappan M, Srinivasan V, Ramanathan N, Taylor J. mWASH: mobile phone applications for the water, sanitation, and hygiene sector. 1st ed. Oakland, US: Pacific Institute; 2012. 115p.

[37] Eawag. Improving understanding of urban sanitation [Internet]. 2016 [Updated: 2016]. Available from: http://www.sfd.susana.org/ [Accessed: 06.04.2016].