RESEARCH REPORT

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FACTS OF ON-SITE SANITATION IN URBAN INDIA

HOW GOVERNMENTS COLLABORATING WITH CITIZENS COULD EVOLVE SAFER AND MORE SUSTAINABLE SANITATION OUTCOMES

Shubhagato Dasgupta | Neha Agarwal | Anindita Mukherjee

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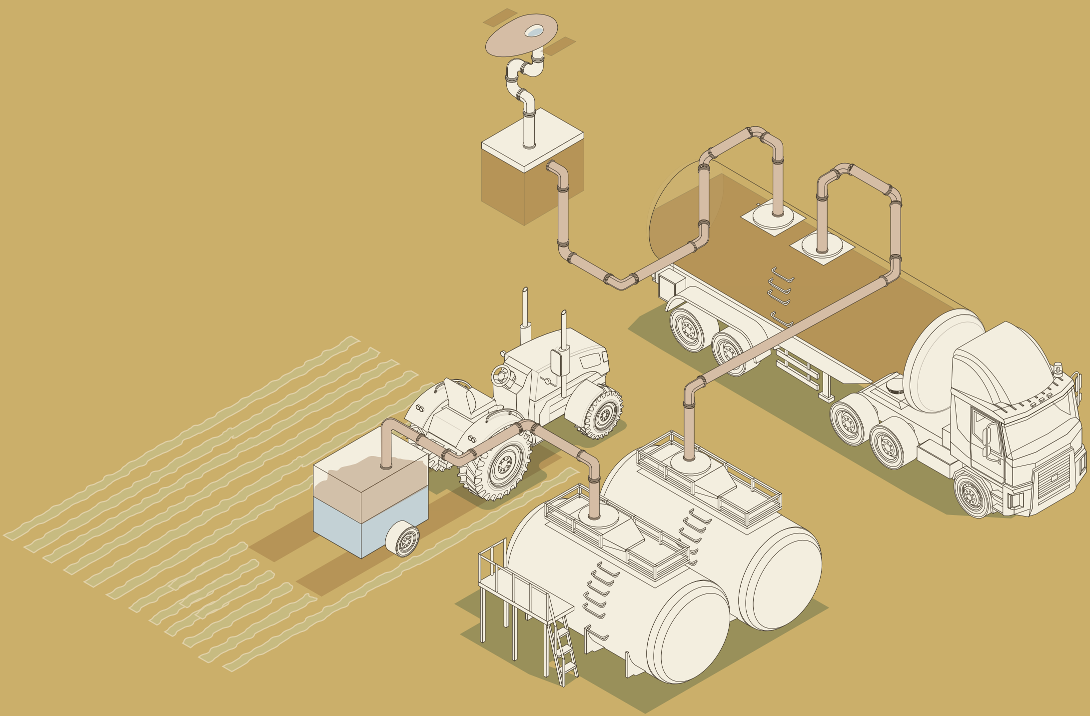

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GLOSSARY

Biochemical Organic Demand (BOD) indicates the amount of biodegradable organic matter in wastewater by measuring the oxygen consumed by microorganisms for its degradation

Blackwater is the wastewater originating from the toilet and comprised of excreta, flush water and anal cleansing water

Desludging is the act of emptying an on-site sanitation system or pumping-out its contents

Effluent is the fluid resulting from a treatment system; specifically within the report, 'tank effluent' has been used to refer to the effluent from a septic tank

Graywater, or sullage, refers to wastewater originating from non-toilet related uses of water such as cooking, washing, bathing, etc.

Septage is the combination of sludge, scum and wastewater contained by the septic tank

Septic tank is the primary treatment unit of a 'septic tank system' where settling of solids and solids-liquid separation, along with partial digestion of settled solids, occur

Septic tank system, conventionally, is an on-site sanitation system comprising a 'septic tank' for primary treatment and a 'subsoil dispersion system' for subsequent remediation and disposal of the tank effluent

Fecal Sludge, or sludge refers to the slurry of solids formed as a result of the processes (such as settling and partial digestion) that wastewater undergoes in an on-site sanitation system

Subsoil dispersion systems, like soak pits and dispersion trenches, succeed a septic tank and disperse its effluent into the surrounding subsurface for its remediation through naturally occurring processes

Total Suspended Solids (TSS) are filterable solids that remain suspended in wastewater and impart turbidity to it

ACRONYMS

ABR	Anaerobic Baffled Reactor
AF	Anaerobic Filter
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BIS	Bureau of Indian Standards
BOD	Biochemical Oxygen Demand
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSO	Cesspool Operator
EPA	Environmental Protection Agency
FSSM	Fecal Sludge and Septage Management
GWS	Groundwater Source
IHHL	Individual Household Latrine
IS	Indian Standard
OSS	On-Site Sanitation
SBM	Swacch Bharat Mission
SCM	Smart City Mission
ULB	Urban Local Body

EXECUTIVE SUMMARY

On-site sanitation systems are very common in urban India. The Census of India 2011 established that more than 28 million urban households depended on on-site sanitation (OSS) systems, such as septic tanks and leaching pits. Access to toilet has increased manifold over the past decade owing to rapid urbanization and the mainstreaming of sanitation through the ongoing national sanitation programme, Swacch Bharat Mission – Urban (SBM-U). As on date, nearly 6 million individual household toilets have been constructed in urban India under the Mission alone. Given the relatively slow rate of growth of the sewerage network, these gains in toilet coverage have further entrenched the reliance on OSS systems.

Despite its prevalence across geographies and socio-economic strata, OSS has received limited institutional attention so far. The codes governing septic tank systems and leaching pits were issued by the Bureau of Indian Standards (BIS) in the 1980s, although remain rarely enforced till date. Construction of these systems proceeds ad hoc, driven by households and informally-trained masons - resulting in non-compliance with governing codes, the degree of which has seldom been measured and reported in the past.

The present study is a unique attempt to systematically analyze the current state of on-site sanitation (OSS) systems in urban India. It documents the detailed typology of these systems as they have evolved on the ground, through an approach combining a household survey and key informant interviews in select states and cities.

Key findings

OSS systems deviate along most of the characteristics specified by the IS codes. These deviations combine to result in a wide variety of systems that have been categorized into seven unique types – single-chambered septic tank (54%), double-chambered septic tank (22%), triple-chambered septic tank (5%), cylindrical septic tank (9%), Balram tanks (1%), single leaching pits (7%), and twin leaching pits (1%).

Septic tanks, the overwhelmingly dominant OSS system (91%), are compliant in less than 2% of cases. The most commonly occurring OSS system is a 'large' primary treatment unit, viz. the septic tank, which discharges inadequately treated effluent into open drains. The majority of these are single-chambered and located underneath the building or the toilet. Septic tanks with soak pits, or a septic tank system as conventionally understood, are less prevalent at 19%.

Leaching pits, although fewer in numbers, present unique design and operation challenges. The self-sustaining twin leaching pits comprise a small proportion of all pit-based systems and are linked to scheme-led constructions. However, this study finds that more than one-third of these lack the functionality for alternating use defeating their objective. Single leaching pits remain comparatively more common, but raise questions about their emptying practices.

OSS systems co-exist with groundwater sources without adequate setbacks compromising sanitation outcomes. In 22% of the cases, households owning an OSS system also reported relying on a groundwater source for their potable water needs. Although household-level water treatment has the potential to reduce emanating health risks, about 70% of the households in this nexus reported consuming the water without any treatment.

Socioeconomic factors drive design decisions instead of hydrogeology and number of users. For both masons and households, a 'tank' requiring emptying in 40-50 years is usually considered the benchmark in system design. Households tend to maximize the size of the OSS system depending on resources and plot size to avoid all future cost of emptying.

Emptying, or desludging of OSS systems remains highly infrequent among the households. The governing code recommends half-yearly or yearly desludging of septic tanks, in keeping with the prescribed size of the tank for a given number of users. As the tanks are larger than the 'ideal' size, only 13% had been emptied at least once in their lifetime. Application of the scientific basis for determining emptying needs at these sizes reveals that 19% of all tanks had been timely emptied.

Pits are more commonly emptied manually than the tanks. In 58% of the cases of emptying- tank based systems, ULB Cesspool operators provided the service. Among pit-based systems, the incidence of manual cleaning was as high as 48%. Overall, in 26% of the cases, an OSS system had been emptied manually at least once in its lifetime.

Masons adapt to local conditions, albeit not those of hydrogeology. Masons, informally trained in all cases and unaware of the governing regulations, disjointedly perceive a connection between OSS systems and hydrogeological factors. Although an outlet to the drain is considered a norm, in regions with sewerage availability, the option to connect tanks to sewer lines is also recognized and utilized.

Broad Recommendations

Contrary to popular perception, OSS systems provide more than a temporary recourse towards fecal waste treatment/management. Due to their 'private good' nature and without regard to their importance for public health, however, these are seldom regulated and are consequently beset by substantial localization. OSS systems are installed by informally trained masons in collaboration with households who remain equally unaware of national standards, often at the expense of the system performance.

While SBM-U may have succeeded at its goal of enhancing access to a toilet facility, it has missed the opportunity to monitor design specifications of OSS systems constructed along-side. The quality of these household-level wastewater management systems, for new and old toilets alike, did not feature within the mandate of the national sanitation programme. Further, in 2017, the National Policy on Fecal Sludge and Septage Management was launched to ensure integrated sanitation service chain, which directed the efforts towards the installation of off-site treatment facilities with inadequate consideration to containment, collection and conveyance. While the two ends of the spectrum have gained traction among the policymakers, the complex and crucial component of OSS systems remains disregarded. Therefore, several interventions are required in design, planning, and regulation to address this deficiency in achieving consistent and sustainable sanitation. In the short-term, ULBs should focus on improving the quality of effluent through timely emptying of septic tanks and the city-wide management of effluent and graywater. For the latter, graded solutions may include covering and intercepting existing drains as a start, but in consideration of the primary role of the drain as stormwater management infrastructure. Innovating in system design, its standardization through prefabrication, and formal quality control and promotion of the resulting systems may ease both planning and regulatory woes in the medium- and long-term. Several countries, such as Malaysia and Japan, have already traversed such a pathway and streamlined end-to-end service delivery for these systems over the decades.

Moving ahead, a paradigm shift is required from treating these systems as 'private units' to viewing them as 'a network of localized wastewater management systems' with profound public health outcomes. Such a network may be treated at par with the centralized system, recognizing that despite their inherent differences, their ultimate goal and the scale are the same. Accordingly, a portfolio of interventions to tackle the complex and multifaceted issue is discussed below.

DESIGN

Train masons in the appropriate design protocol, mainstreaming enhanced versions of existing technologies

Empanel masons for quality control and continued engagement

Revise existing OSS standards for addressing contemporary concerns of settlement densities

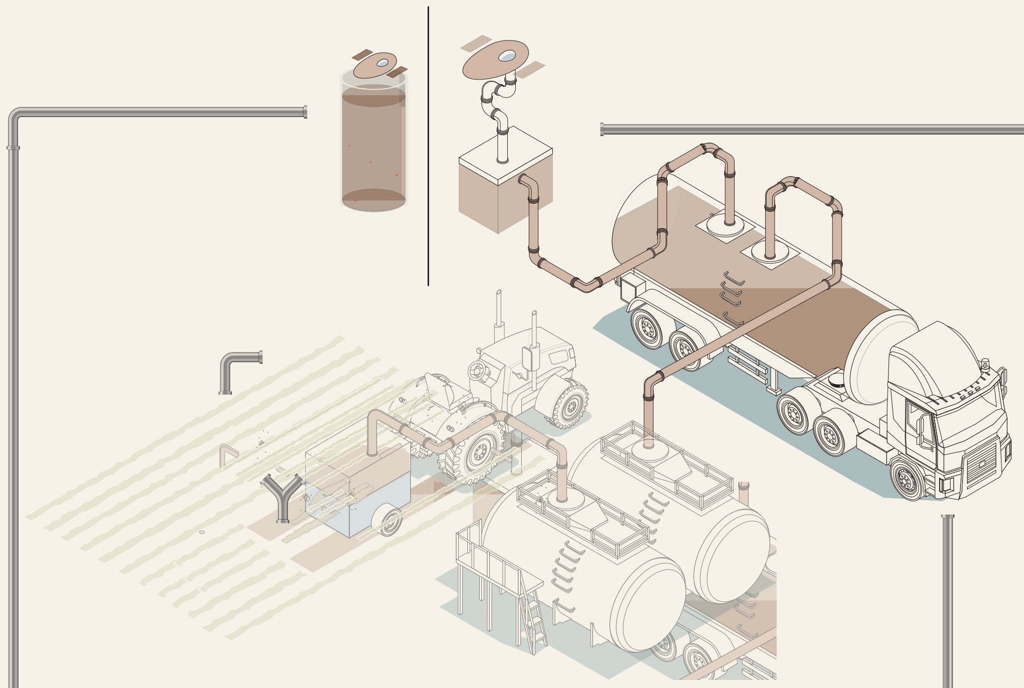
- **Specify performance standards for OSS systems** – either through linking with existing quality parameters or a new graded standard
- **Facilitate research and development** towards modular and prefabricated OSS systems
- **Mainstream modular,** prefab alternatives through tie-ups with local sanitary marts, collaborating with masons, among others
- **Develop standards and certification methods** for prefabricated systems to comply with
- **Undertake periodic inspection of OSS systems** based on a schedule to ascertain compliance and performance

PLANNING

- **Create data on OSS** systems for planning and monitoring
- **Design a timely emptying framework** for systems on the basis of OSS system characteristics in the city
- **Undertake micro-planning** to devise retrofitting strategies for technological improvements in individual OSS systems
- **Ensure access to safe water supply** targeting those with toilet access (and concomitantly, OSS systems)

GOVERNANCE

- **Ensure mechanized emptying of OSS** systems through procurement of requisite equipment
- **Sensitize households** towards safer and more sustainable OSS systems
- **Develop ULB capacity and competency** by undertaking training, instituting nodal agency for continued technical support and guidance
- **Create accountability mechanisms** for local-level regulators focused on measuring local performance and grievance redressal
- **Ensure continued allocation of earmarked** resources towards the creation of a fully functional sanitation service chain
- **Create operative guidelines** and procedures for service providers
- **Institute structural reforms** focused on creating specific roles and positions for the management of sanitation



81% OSS systems are rectangular 'septic tanks'

69% of reported groundwater sources lie within 10 meters of an OSS system

DESIGN OF TANKS

2% of all tank-based systems comply with IS code specifications

85% of all tank-based systems at least double the size prescribed by IS code

68% of all tank-based systems requiring partitioning are single-chambered

65% of all tank-based systems discharge effluent into drains

DESIGN OF PITS

26% of subsidy led in-house toilets are accompanied by a pit-based system

88% of all pit-based systems are single leaching pits

37% of twin pits lack alternating use

EMPTYING OF SYSTEMS

81% of tank-based systems needing emptying had never been emptied

48% of all pit-based systems were manually cleaned during last incidence of desludging

3x Manual emptying is 3 times more common among pit-based systems compared to tanks

INTRODUCTION

BACKGROUND AND RATIONALE

The achievement of sustainable sanitation outcomes depends not only on the access to a toilet facility but also on well-functioning wastewater management systems. In line with this, the last few years have witnessed the mainstreaming of the entire sanitation service chain: the collection, conveyance, treatment of the wastewater, and safe recycle or disposal of resulting by-products, albeit primarily through policy instruments.

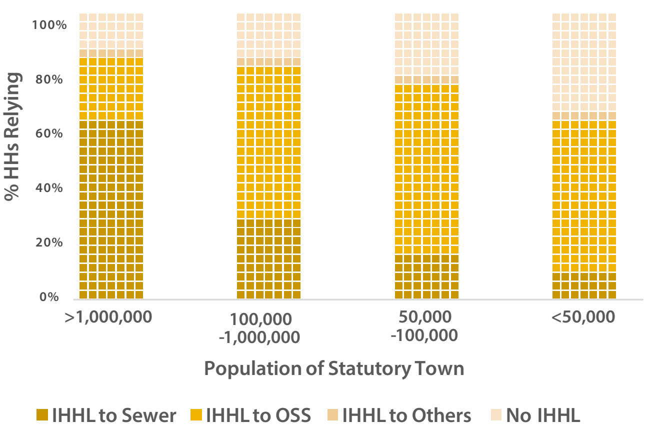
The centralized sewer system is viewed as the gold standard in wastewater management. The system first emerged in Europe during the twentieth century in response to burgeoning populations, higher wastewater generation rates, and the ineffectiveness of contemporary decentralized technologies (Angelakis, 2015). Nonetheless, its penetration remains low in most developing regions of the world, including India, which continue to rely on 'OSS' systems, such as single pit latrines, twin pits, and the septic tank system, among others. Of these, the first septic tank system was designed and patented in the 1880s by John Mouras in France (Beder, 1993). The following years saw its proliferation and, consequent regulation in several parts of the world, such as its prohibition on premises accessible to a sewer system or in high water table regions (Maine DHHS, 2013).

India's commitment to sanitation, emerging as a priority only in the 1980s, led to the formation of a technical advisory group comprising several international agencies and members from the Indian government (the World Bank, UNICEF, and UNDP) in 1983. The group recommended the twin-pit pour flush latrine as a cost-effective sanitation solution in both rural and urban areas, which remains a continuing technological preference in national programmes to this day (UNICEF, 2002). But a comparison of the types of toilet facilities reportedly in use by urban India between 2001 and 2011 underscores a transition towards water closet-based technologies such as sewers and septic tanks. Further, the demonstrable shift in preference has not been endemic only to urban areas but has been observed along the entirety of the rural-urban continuum (Dasgupta, Roy, Bhol, & Raj, 2017).

Overall, as per the latest Census, 52% of all toilet-owning households in urban India, ranging from the sporadic unserved pockets in metropolitans and big cities to the whole population in smaller towns, rely on OSS systems (Figure 1). These systems have also accompanied the unprecedented gains in toilet coverage produced under the Swacch Bharat Mission (SBM). Coupled with the slow pace of network expansion - underwritten by schemes like the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and the Smart Cities Mission (SCM) in only 500 statutory towns out of a total of 4041 - this means that the reliance on OSS is unlikely to erode in the foreseeable future. But, it is crucial to note that due to their decentralized nature, the entire spectrum of related decisions and responsibilities are relegated to the full authority of the households, with a near complete absence of institutional oversight.

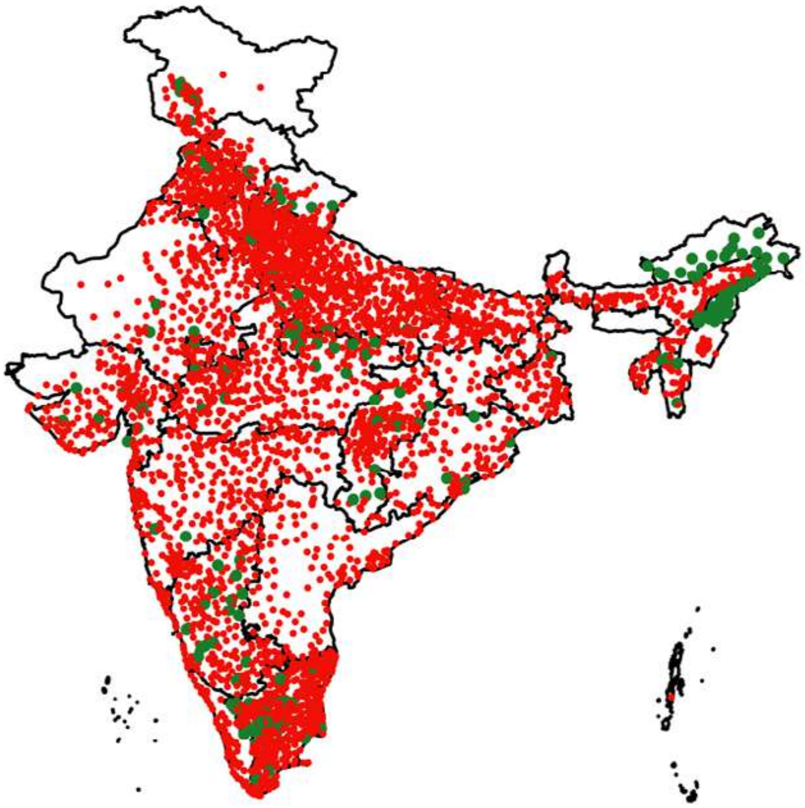
Although the government, recognizing the continually high dependence on OSS, promulgated the National Policy on Faecal Sludge and Septage Management (FSSM) in 2017, it hasn't focused adequately on the quality of household-level infrastructure. Accordingly, the dominant response of individual states has been to plan for scheduled desludging services and construct facilities for off-site treatment of septage (SeTPs). Meanwhile, the risks from ill management of effluent, intended leachate, and unintended leakages remain unrecognized, missing even from the typical schematics of the sanitation service chain (Mitchell, Abeysuriya, & Ross, 2016). It suffices to say that the state of individual OSS systems – the first and most crucial link in the sanitation service chain – remains unassessed.

Figure 1 ***Prevalence of various types of Individual Household Latrines (IHHLs) across city sizes***



Although limited, the existing national literature points to the phenomenon of hydraulic overloading causing system failures and release of inadequately treated

Figure 2 Spatial density of septic tanks in urban India, each point on the map representing a statutory town (as per Census 2011)



wastewater into the surrounding environment (Centre for Science and Environment, 2011) and the impact of lateral distance between toilets and groundwater sources (GWS) on the latter's quality in the cities of Calicut (Harikumar & Madhava, 2013), Agra (Quamar, Jangam, Veligeti, Chintalapudi, & Janipella, 2017), Indore and Kolkata (Pujari et al., 2007; Pujari, Padmakar, Labhasetwar, Mahore, & Ganguly, 2012).

As early as the 1970s, the United States Environmental Protection Agency noted that while 'properly designed, constructed and operated septic tank systems' are 'an efficient and economical alternative to public sewer systems, particularly in rural and sparsely developed suburban areas', they have also 'demonstrated the potential for contamination of ground and surface waters' (Scalf, Dunlap, & Kreissl, 1977). With increasing system density, the soil's capacity to treat the effluent, even in the best suited hydrogeological environments, is compromised, thereby increasing the potential for contamination of groundwater (Yates, 1985). Several studies have since substantiated the impacts of high septic tank system density internationally, including both the role of septic tank systems in disease outbreaks (Craun, 1979) and the quality degradation of surface and ground waters, especially in relation to the presence of nitrates (Arwenyo, Wasswa, Nyeko, & Kasozi, 2017; Borchardt, Chyou, DeVries, & Belongia, 2003; Withers, Jordan, May, Jarvie, & Deal, 2014). The principle underlying the investigation can be extended to include other OSS technologies which also rely on subsurface dispersion such as leaching pits.

The earliest studies deemed a density of more than 15 septic tank systems per square kilometre to be relatively high in the USA and as possessing a considerable potential for regional contamination (Yates, 1985). A later investigation pegged the control limit at 41-49 septic tank systems per square kilometre specific to its local context (Hansen, 2016). The density of septic tanks in Indian statutory towns exceeds the earlier threshold by order of magnitude of 20 or more (Figure 2). This consideration, currently applicable in limited cases (viz, soak pits and single and twin leaching pits), gains in importance during the planning of improvements to the current state of OSS. Therefore, the limitations of even a fully compliant septic tank system and those of leaching pits in certain spatial settings are required to be recognized and reckoned with going forward. Doing so may render soak pits an unviable addition to the existing tanks (to retrofit) and an ineffective requirement for new ones.

While the increase in toilet access and usage accrued in the last few years is commendable, the achievement only partially furthers the objective of securing safe and sustainable sanitation. Without ensuring the waste thus engendered is contained and treated, the benefits of sanitation – from decreased infant and child mortality (Alemu, 2017) to improved education outcomes and productivity (Günther & Fink, 2011) – cannot be fully realized.

APPROACH AND METHODOLOGY

In the past, nationally representative surveys like the Census and NSS have attempted to map the sanitation choices at the household level, but the bracketing of the several variations in OSS systems under the broad headers of 'septic tank', 'pits with slabs', 'pits without slabs', among others, results in a loss of critical details. The scarcity of information not only acts as a significant impediment to effective planning and monitoring of outcomes at the local level but also leads to the reliance of policymakers on sweeping (and possibly flawed) assumptions while designing new intervening regulations. Therefore, meaningfully detailed data is critical to charting the course of the national sanitation agenda forward.

In view of this, the present study undertook a sample survey in ten Indian cities to investigate the typology of OSS systems and the ensuing maintenance practised by the households. Additionally, in-depth interviews were conducted with governmental stakeholders (ULB engineer, ULB health officer, SBM contractor, public cesspool operator) and non-governmental ones (mason, private cesspool operator, manual cleaner), in each city, to contextualize the quantitative findings.

The sites of inquiry, smaller cities with limited sewerage, were chosen through a multi-stage selection strategy (Figure 3). In each city, ten wards were selected based on spatial inclusion criteria which accounted for the presence of water bodies, highways, railway tracks, the spatial distribution of the ward, among others. The total sample of 3000 households was distributed equally across the wards and cities, resulting overall in a confidence level of 99% and a margin of error less of than 5%.

Uniqueness

While a consensus around limited oversight leading to the wide variation of the systems from standards has been slowly building within the community of practitioners and researchers, the present study is one of the first attempts to qualify it systematically. Information across a range of locations has been collected, quantified, and processed to test the commonly held notions concerning the practices of OSS in urban environments. The size and nature of the deviations have been assessed to identify key points of interventions, the most crucial of which have also been addressed as part of the report.

Field testing of the survey instruments showed that the terminology employed by households to describe their OSS system varies from region to region and may be misleading. As a result, the present study adopted a bottom-up approach to ascertain the 'type' of system. Instead of asking households to state the name of the sanitation system in use, the survey collected data about its specific attributes. These attributes were then combined to form a complete picture of the system and assigned a 'name' or a 'type' thereafter.

Limitations

Owing to the focus of the study on OSS systems, the sampling was purposive to limit the number of samples falling in other categories. Therefore, the distribution of the sample across the categories of 'households owning IHHL connected to sewer/OSS system/drainage/bio-digestor' and 'households not owning IHHL' cannot be compared to existing secondary data (Table 1).

As another direct consequence of the specific goal of the study, it did not delve into an in-depth investigation of the toilet usage behaviour of households. Consequently, the social desirability bias, which often colours responses in this regard, may not have been adequately countered. Additionally, the responses of the households in stating the nature of the settlement (slum, unauthorized colony, authorized colony, resettlement colony, authorized colony) in which they reside may not be entirely reliable, given the complexity of administrative classification.

Since the survey spanned a significant number of households in a limited timeframe, a detailed physical inspection of the OSS systems to verify the attributes reported by the households could not be undertaken. In collecting the data on water supply, only those households which reported reliance on groundwater sources were questioned further about its location – as opposed to obtaining the particular information from all households regardless of whether or not they rely on such a source. Their exemption from the question may have led to an underreporting of the true extent of the OSS and groundwater nexus.

Additionally, the physiochemical characterization of the effluent and a quantitative assessment of the quality of water from tubewells/boreholers were not conducted as part of the present study.

Table 1 Distribution of survey sample

HHs with IHHL connected to		HHs without IHHL	
sewer	3.6%	shared toilet	1.3%
on-site sanitation	74.7%	public toilet	0.3%
open drain	2.9%	community toilet	0.6%
closed drain	0.7%	open defeca-tion	15.5%
open ground	0.5%		
Total	**82.3%**		**17.7%**

Organization of the Report

Each of the three chapters, following the present introduction, is geared towards addressing a specific aspect of OSS:

Chapter 2: 'Addressing Deviations' that existing OSS systems exhibit

Chapter 3: 'Addressing Unification' b etween the immediate physio-social environment within which these systems exist and the higher regulatory environment

Chapter 4: 'Addressing Collaboration', both vertical and horizontal, among the various stakeholders for the long-term sustainability of outcomes

Since the goal of the present report is to describe the current situation alongside the approaches and mechanisms for its improvement, each chapter is subdivided into two sections: What we find on the ground and What can be done.

What we find on the ground discusses the findings from the survey and key informant interviews.

What can be done presents recommendations – market-based, technical, and in policy and regulation – to correct for the key deficiencies.

BOX 1 THE SCIENCE OF ON-SITE SANITATION

A conventional septic tank system comprises two components: a septic tank and a subsoil dispersion system such as a soak pit or a dispersion trench. The incoming wastewater first enters the tank where it undergoes the separation of settleable solids. For the purpose, multi-chambered tanks have been observed to achieve better solids separation than single-chambered tanks (D'Amato & Liehr, 2008). While not designed to remove nitrogen, phosphorous and pathogens, the tank converts simple sugars and fats to methane and carbon dioxide.

Nearly a third of the settled solids get digested over time and the remaining accumulated materials, referred to as 'sludge', collect in the tank. As the volume of the sludge builds up in the tank, the retention period, and subsequently settling, for the incoming wastewater reduce. Therefore, the accumulated sludge must be removed periodically to ensure sustained efficiency of the tank function.

The tank imparts only primary treatment, and although susceptible to fluctuations in performance due to temperature, has a BOD and TSS reducing rate of up to 50% and 70% respectively (CPHEEO, 2012). The resulting effluent, therefore, must be treated further before being released into the open environment.

A subsoil dispersion system disperses the partly treated tank effluent into the surrounding subsurface where naturally occurring processes (such as filtration, adsorption, and decomposition) effect further remediation. The soil retains both microbiological and chemical pollutants depending on its composition, and the treated effluent disperses into the groundwater thereafter.

Twin leaching pits, also known as 'alternating twin pits' – which accomplish the tasks of containment of wastewater, treatment of sludge, and disposal of effluent all in one system – consist of two pits linked through a Y-junction to the water closet. At a given time, only one of the pits is used and left undisturbed for a few years upon its filling for complete sanitization of the accumulated materials. During this period, the wastewater is managed through the second pit. Considerations of hydrogeological suitability aside, the technology is especially suited to areas where mechanized services for the removal of sludge from the system may not be available since, at the end of the recommended storage period, the sludge is safe to evacuate manually and for use as a soil conditioner.

Figure 3 *Site selection framework and list of selected sites*

STATE

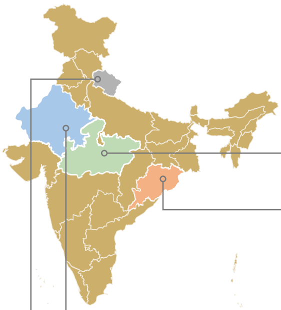
- Reliance on on-site sanitation
- Urbanization and development
- Depth to groundwater
- Topography and soil type

DISTRICT

- Reliance on on-site sanitation
- Reliance on groundwater sources
- Access to individual household latrine (IHHL)

CITY

- Urbanization



State	City
Madhya Pradesh	Katni
	Sehore
Odisha	Bargarh
	Dhenkanal
	Jharsuguda
Rajasthan	Alwar
	Jaisalmer
	Rajsamand
Uttarakhand	Dehradun
	Rudrapur

BOX 2 THE STANDARDS OF ON-SITE SANITATION

The Indian Standard Code 2470, Parts I and II, jointly govern the design and installation of septic tank systems and recognize that the 'unsatisfactory design, layout, construction and maintenance of septic tanks constitute a health hazard'. It specifies not only the requirements for the structure design but also operational practices which contribute to the continued efficiency of the system.

Structural Fidelity	Operational Efficiency
watertight floor and walls	excessive detergents, grease, disinfectants not to be added
chambers for tanks larger than 2000 litres	yearly or half yearly desludged
ventilation pipe	portion of sludge left behind while emptying as inoculum
access opening	
secondary treatment system	

Further, the code states that septic tanks only 'offer a preliminary treatment of sewage'; the residual organic and suspended matter from the tank 'will cause a health hazard if the effluent is not adequately disposed of'. As per the code, the effluent from a septic tank 'should be given secondary treatment either in a biological filter (such as an upflow anaerobic filter) on the land or in a subsurface disposal system'. With regards to effluent management, the code also states that 'under no circumstances should effluent from a septic tank be allowed into an open channel drain or body of water without adequate treatment'. It further states that where none of these methods is feasible, and the effluent has to be discharged into an open drain, 'it should be disinfected'.

The Indian Standard Code 12314 pertains to 'leaching pits' as opposed to 'twin leaching pits' specifically, but does state that 'single leach pits are appropriate only if they can be desludged mechanically by a vacuum tanker since their contents contain pathogen'. The code defines 'pits where the groundwater table is below the bottom of the pit throughout the year' as 'dry pits', and 'wet pits' otherwise, to establish safety requirements. In the case that the distance between the pit bottom and groundwater table is less than 2 meters at any point in the year, the code requires the sealing of the pit's bottom and provisioning of a sand or soil envelope around it. In black cotton soils, 'a vertical fill 300 mm in width with gravel or ballast should

BOX 2 *CONTINUED*

be provided around the pit outside the lining.'

The contents of the pit upon its filling 'must be allowed to digest and remain undisturbed for at least two years, when it will not be hazardous to handle the digested humus'.

While the code for both the septic tank system and twin leaching pits prescribes the methods in design and installation of the system and dictates the norms for effluent management, it does not lay down specific quality criteria that must be met by the effluent before its discharge into the subsurface or drainage. However, a reference can be found in the Schedule VI of the Environment Protection Rules, 1986, which lists the quality requirements for effluent depending on the ultimate discharge point: inland surface water, public sewer, land for irrigation and marine coastal areas.

The codes also prescribe the minimum setback distance of soak pits and leaching points from a groundwater source, as a safeguard against its contamination. A dry pit can be located at a minimum distance of 3 metres and a wet pit at a minimum distance of 10 metres from groundwater sources such as tubewells and dugwells, if the effective size of the soil is 0.2 mm or less. When the soil is coarse, these distances can still be maintained for each type of pit if its bottom is sealed off and an envelope of fine sand is provided around it. Similarly, the code requires maintaining a distance of 18 metres between a subsoil dispersion system accompanying a septic tank and such a source.


BDC

2 ADDRESSING DEVIATIONS FOR SAFETY

Several factors taken together characterize an on-site sanitation system. The technical standards issued by the Bureau of Indian Standards – the Indian Standard Codes 2470 (Part I and II) and 12314, and echoed by the CPHEEO manual, building bye-laws, among others, present the specifications for each of these. The present chapter discusses the on-ground typology of OSS systems and analyses their compliance with the governing codes.

Challenges

Single-chambered tanks constitute more than half of all OSS systems. Pit-based systems are rarer but remain more prevalent among subsidy-led IHHLs.

Less than 2% of all tank-based systems are compliant to the IS code. Although 90% require immediate interventions for enhancing their performance, nearly 80% are located underneath the toilet or building.

Twin leaching pits are modified through an interconnection with the intent of extending desludging frequency, but mitigatory steps in high-risk settings are not adopted.

Opportunities

Effluent management emerges as a pressing need to be fulfilled through novel models, recognizing that soak pits may be untenable - despite suitability of hydrogeological settings - in dense spatial settings .

Innovations in the OSS system itself and mainstreaming of more efficient primary units would enhance their safety in the long-term.

Technical standards would have to adapt to contemporary concerns unique to urban settings and enhance their implementability.

WHAT WE FIND ON THE GROUND

'Safety,' a multi-faceted notion when applied to an OSS system, can manifest as the extent of treatment it imparts, as the ease of maintenance it offers, and in its interaction with the surrounding environment. The present section delves into the typology of these systems and evaluates the safety they provide. Accordingly, the first part discusses the key trends across various types of OSS systems. The second and third parts assess, respectively, the deviations observed in tank-based systems and pit-based systems from IS code governing their design and installation.

As part of the assessment, the authors have developed a framework to analyze and evaluate these systems for their safety – defined not only through design, but also the nature of maintenance. Of these, the latter is dealt with in greater detail in Chapter 4 of this report.

a. Typology of On-site Sanitation Systems

On-site sanitation systems present a complex reality in urban India. Existing secondary data sources such as the Census of India and the National Sample Survey describe whether a toilet facility in use is connected to a sewer, a septic tank, a pit (with and without slabs), or if it is a service latrine or a bio-toilet. The differentiation, while useful for understanding the dependence on various technological options, does not speak to the quality of the infrastructure itself. In other words, these data sources do not distinguish between a fully compliant OSS system and one which may be ill-constructed and performing inadequately.

A meaningful description of an on-site sanitation system would allow assessing its suitability in a given setting, or the extent of its adherence to design specifications. Several attributes thus are required to understand the typology of these systems. These include, but are not limited to:

- Type and material of the wall and floor lining
- Shape and dimensions of the system
- Number of chambers
- Presence of ventilation pipe and access lid
- Effluent management method of the system
- Location of the system

The present study finds that OSS systems on the ground present variations along each of these dimensions to create a complex reality of on-site sanitation in urban India (Figure 2). The myriad combinations have been condensed into seven unique types using the data on the shape, water-tightness, and chambering (for tanks) of the observed systems (Table 2).

Septic tanks are the overwhelmingly dominant choice in sanitation technology. The study finds that nine out of ten OSS systems are septic tanks – or watertight containment units which impart primary treatment, with varying effluent disposal methods. Their prevalence over the years seems to have persevered, given that 87% of all OSS-dependent households employed a septic tank as per Census 2011. Pit-based systems, such as twin leach pits and single pit, were observed to be present at a lower rate than Census 2011 findings - 8.2%, comparable to the 13% proportion found in 2011. Like tank-based systems, both cuboidal and cylindrical pits were reported.[1]

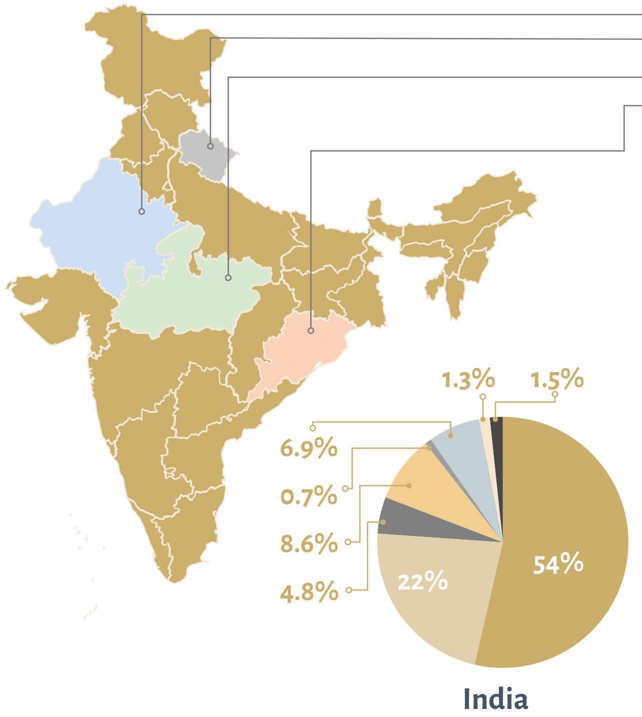
OSS systems are usually employed only for blackwater management, with graywater being directly discharged without any remediation. The data shows that 92% of systems are employed by households for the management of only blackwater and by 7% for both blackwater and graywater. The absence of an open drain is significantly associated with such mixed-use. Pit-based systems employed in such a scenario are 36% larger on average than those that are not. Tank-based systems with and without mixed-use do not exhibit such a difference, possibly since the mean tank size is greater than 12,000 liters in both the instances. On the whole, graywater, which may constitute as much as three-fourths of the total domestic wastewater generated and contain chemical pollutants, is disposed directly into stormwater drains in 90% of the cases.

b. State of the Tanks

Septic tanks are 'large', inefficient for their size and poorly accessible. The study finds that the typical urban Indian septic tank, confused in common parlance and practice for a complete system, is a single-chambered rectangular tank, 13,375 litres in volume on average, and constructed

1 'Tank with leaching bottoms' is the term that is often colloquially applied by practitioners and researchers to the former of these.

Table 2 *Types of OSS systems used by surveyed households, distributed across selected states*



System Type pie	Odisha	MP	Uttara-khand	Rajas-than
Single-chambered septic tank	39.3%		56.9%	56.9%
double-chambered septic tank	37.4%	18.5%	10.7%	21.1%
triple-chambered septic tank	9.8%	0.5%	2.1%	5.3%
cylindrical septic tank	8.5%	1.3%	15.2%	8.2%
Balram tanks[2]	0.2%	1.6%	0.9%	0.3%
single leaching pits	3.5%	7.9%	11.4%	5.8%
twin leaching pits	0.8%	4.7%	0.4%	0.3%
can't say	0.6%	1.1%	2.4%	2.0%

underneath the building or the toilet. Nearly 85% of all tank-based systems are at least double and 37% more than eight times the sizes prescribed in the IS code[3]. The code also recommends partitioning for tanks larger than 2000 liters to facilitate better flow dynamics and solids settling. However, only 32% of tank-based systems fulfill this requirement raising concerns about the hydraulic efficiency of these units.

While many of these tanks may require rehabilitation or retrofitting to ensure safe sanitation, more than 80% of the tanks are reported to be located underneath the building or the toilet – posing a challenge to these interventions. Overall, less than 2% of septic tanks comply with all the major requirements of the IS code.

Tank effluent, primary-treated in varying degrees, is not subject to further treatment before its release into the environment. The effluent from such a tank typically requires further management, but the ground reality reflects a grave lack of attention to its management. As per the code, the effluent must not be allowed into an open drain or body of water under any circumstances, but the data reveals that tank effluent from 65% of the units is discharged directly into drains. These drains were reportedly uncovered in 82% of the cases.

Interestingly, 41% of the tank-based systems constructed with public subsidy have been reported to be accompanied by a soak pit (Table 3) – in practical realization of a conventional septic tank system. The highest occurrence of soak pits has been reported in the state of Uttarakhand for both subsidy-led and privately constructed IHHLs, at 41% and 37% respectively.

For cities beginning to be sewered, connecting through outlet of septic tank is common. Interestingly, 53% of sewered households have reportedly connected to the sewer line through the existing septic tank outlet as opposed to directly to the water closet. The phenomenon seems to be least common in Uttarakhand and most common in Madhya Pradesh, where sewer lines were being the laid down at the time of data collection. Households perceived the sewer networks to be unreliable and 'to avoid backing up of wastewater into not just the toilets, but more importantly, through connections to the kitchen', they prefer to continue using septic tanks as an intermediary.

2 'Balram Tanks' is a prefabricated system of two cylindrical, inter-connected tanks. The two tanks in such a configuration serve as the two chambers of a conventional rectangular septic tank.

3 For a given household size and a desludging frequency of two years.

BOX 3 SANITATION SAFETY OFFERED BY SEPTIC TANKS AND PITS

In order to determine the extent of compliance with the governing IS code and the safety exhibited by the two key types of OSS systems in an integrated manner, the present study adopted the following set of frameworks. The overall compliance has been measured through the several design aspects listed in the code. On the other hand, both design and maintenance have been considered in the assessment of the system safety.

Figure 4 *Safety Score for Tanks (out of 10)*

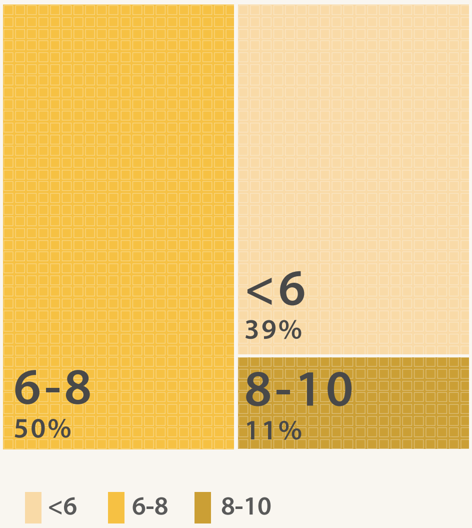
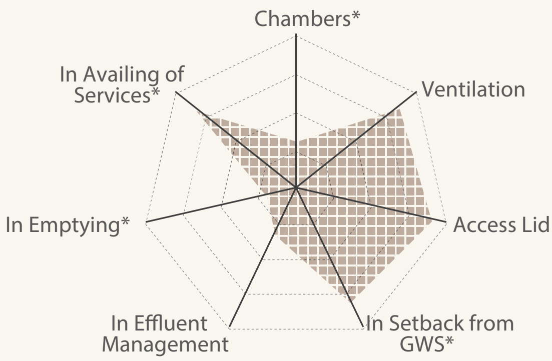


Figure 5 *Disaggregating Septic Tank Safety*



*These categories contain a subset of the total number of observations since a) tanks lesser than 2000 liters do not necessarily require chambering, b) not all septic tanks require emptying or have reported being emptied even once in their lifetime, and c) not all households have reported reliance on a groundwater source for potable purposes.

SEPTIC TANK					
Attribute	**Weight**	**Component**	**Specific**	**Weight**	**Description**
Compliant		-			Based on IS code fulfillment of criteria – if all fulfilled 1, if some or none fulfilled 0
Safe in	2	Design	Chambers	0.34	If adequate based on size 1, if not 0
			Ventilation	0.33	If ventilation provided 1, if not 0
			Access Lid	0.33	If access lid provided 1, if not 0
			TOTAL	-	
	2	Setback from GWS	Setback Distance	-	If distance of system from GWS > 18m 1, if not 0
	2	Effluent Management	Outflow	-	If sewer/no outlet/soak pit 1, if closed drain/open drain/can't say 0
	2	Maintenance	Emptying	-	If timely emptied 1, if not 0
	2	Availment of Services	Service Provider	-	If mechanized 1, if manual 0
Total Score (out of 10)			-		

Figure 6 *Safety Score for Pits (out of 10)*

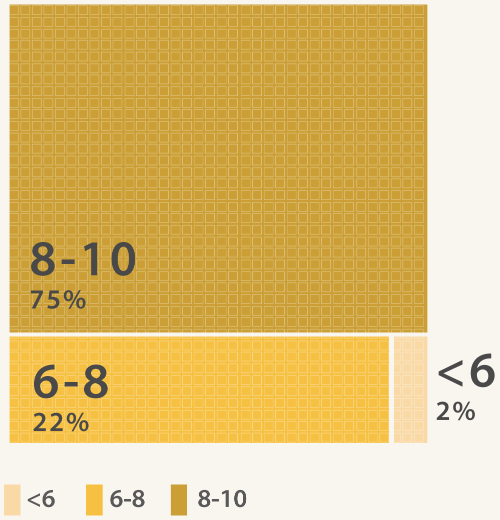
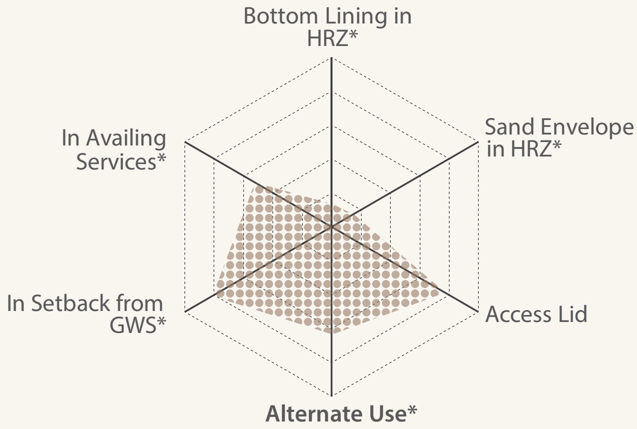


Figure 7 *Disaggregating Pit Safety*



*These categories contain a subset of the total number of observations since a) not all pit-based systems are in a High Risk Zone (HRZ), b) alternating use functionality is applicable to only twin pits, c) not all systems are in the vicinity of groundwater-sources, and d) only a fraction of pit-based systems have ever availed desludging services.

LEACHING PIT					
Attribute	**Weight**	**Component**	**Specific**	**Weight**	**Description**
Compliant					Based on IS Code fulfillment of criteria – if all fulfilled 1, if some or none fulfilled 0
Safe in	2.5	Design	Bottom Lining in HRZ	0.25	If pit bottom is sealed 1, if not 0
			Sand Envelope in HRZ	0.25	If sand envelope provided 1, if not 0
			Access Lid	0.25	If access lid provided 1, if not 0
			Alternate Use	0.25	If alternate use provided 1, if not 0
			TOTAL		
	2.5	Setback from GWS	Setback Distance		If setback distance adequate 1, if not 0
	2.5	Maintenance	Emptying		If timely emptied 1, if not 0
	2.5	Availing of Services	Service Provider		If mechanized 1, if manual 0
Total Score (out of 10)					

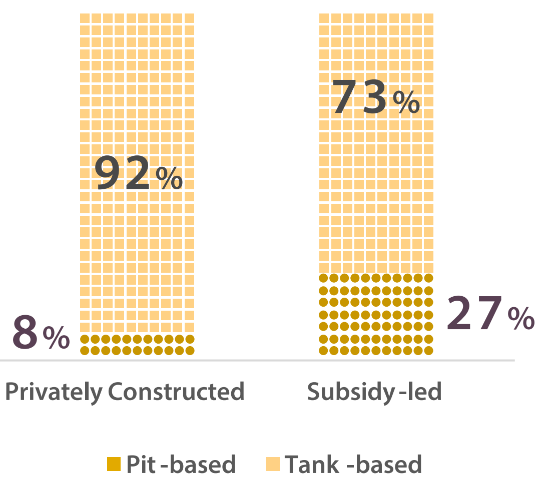
Table 3 Types of secondary management practices adopted by surveyed households

System Type	Soak Pit	Sewer	Drains	No Outlet	Can't Say
single-chambered septic tank	15.5%	7.0%	69.4%	1.3%	6.7%
double-chambered septic tank	14.3%	10.9%	63.5%	2.5%	8.8%
triple-chambered septic tank	13.7%	0.0%	83.2%	0.0%	3.2%
cylindrical septic tank	55.6%	4.1%	30.8%	0.6%	8.9%
Balram tanks	23.1%	0.0%	76.9%	0.0%	0.0%

c. State of Pits

Pit-based systems received a boost under subsidy-led IHHL construction, but single pits are more common than twin pits. The fraction of pit-based systems increases nearly fourfold from an overall 6.6% to 26% when the toilets are constructed through public subsidy (Figure 1). It is also important to note that among publicly-funded IHHLs, single leach pits (15%) remained more common than twin pits (11%). Overall, 88% of all reported pit-based systems are single pits. The code deems the former safe only if mechanically emptied (Bureau of Indian Standards, 1987).

Figure 8 Pattern of systems across different modes of IHHL construction



Twin-pits are modified to eliminate the functionality of alternating use. It is observed that 37% of the twin leach pits do not allow for alternating use, since the two pits are connected through a pipe and remain simultaneously in use. Thus, these resulting 'pits in series' fail in delivering the benefits of a twin pit system over a single pit. Households commonly believe that interconnecting the two pits reduces the requirement of emptying them – a counterproductive notion since, by their very design, twin pits are meant to eliminate the need for mechanical emptying. The phenomenon is also evidenced in rural settings, with households believing that such simultaneous use results in a 'larger' pit (Gupta et al., 2019).

Leaching pits in high-risk zones[3] do not exhibit mitigatory modifications. For pit-based systems to be safe in high water table regions, the governing code recommends sealing the pit bottom and seating the pit in a sand envelope. 22% of pit-based systems in this setting had been provided with neither and 65% had only one of the two characteristics. Similarly, 86% of pits in clayey soils – which require a sand envelope for facilitating their performance – were constructed without it. Leaching pits – single or twin, both of which are thought to have greatly increased under SBM – may require upgradation, especially considering how urban poor settlements (the principal beneficiaries of the programme) tend to be in more congested settings than the region as a whole.

WHAT CAN BE DONE

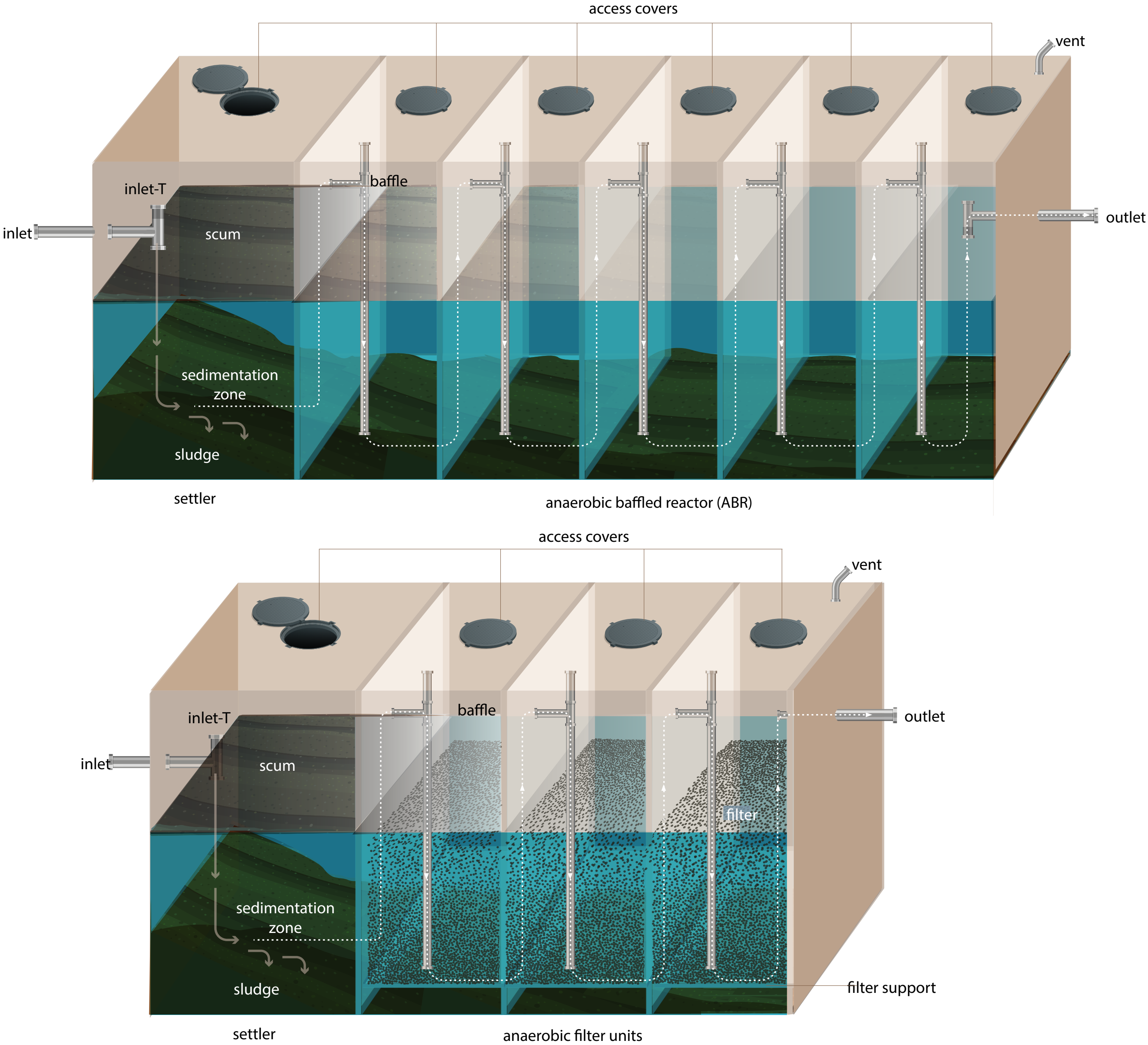
The state of on-site sanitation systems, especially septic tanks, demands immediate attention. While the future of on-site sanitation would benefit from improved technical standards and their realization on the ground through certified and prefabricated systems, the non-compliance of existing systems requires addressal. This first and second parts of the current section discuss the former two, respectively. The management of tank effluent, an essential requirement for the latter, has been dealt with in the third part.

a. Retrofitting and Innovating

Enhancement of the septic tank and its standardisation through prefabrication would render it a sustainably safer technology choice. The Anaerobic Baffled Reactor (ABR), is also referred to as 'improved septic tank' (Tilley, Luethi, Morel, Zurbbruegg, & Schertenleib, 2008). The distinguishing

3 High risk zone refers to the scenarios determined by IS Code as requiring special measures – incidences of wet pit and of a dry pit when the groundwater table is less than 2m below the pit bottom at any time of the year (post-monsoon groundwater depth used as the indicative minimum depth)

Figure 9 Anaerobic baffled reactor (top) and anaerobic filter (bottom) (Source: https://sswm.info/)



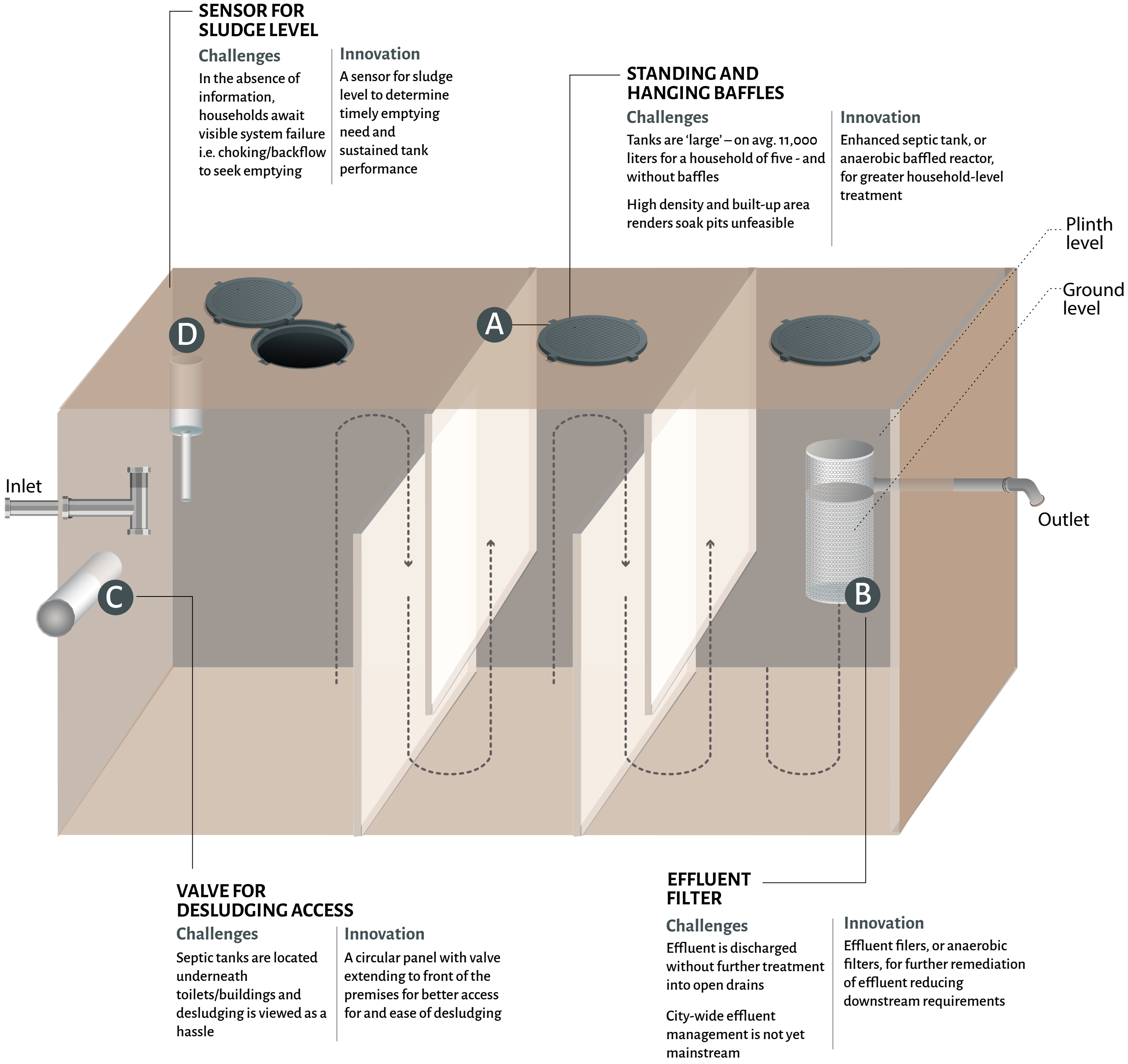
feature of the technology is the 'upflow' nature of inter-compartmental wastewater transfer, which can result in a BOD reduction rate of up to 90%. The possibility of retrofitting existing tanks to render them an ABR, however, would have to be evaluated on a case-by-case basis.

The BIS code governing the design and installation of secondary treatment facilities for tank effluent also recommends the installation of both ABR and AF. However, given their relatively complicated design and construction, the prefabrication and distribution of modular systems could be an opportunity for main-streaming these. Institutionally, the CPHEEO exhibits a forward-looking, albeit tokenistic approach, through recognizing technologies such as the Japanese Johka-sou system in the 'Manual on Sewerage and Sewage Treatment' (CPHEEO, 2012).

Nationally, several suppliers of prefabricated 'septic tanks' (as opposed to a septic tank system) market their products online[4], but a lack of regulatory oversight can lead to the spread of subpar systems as has been in the case of small-scale treatment plants (Banerji, 2018). These tanks are modular, available in materials such as Fiber Reinforced Plastic (FRP) and Reinforced Cement Concrete (RCC), and usually multi-chambered. But, there is a dearth of advanced prefabricated systems

4 United Septic Tanks (http://www.unitedseptictanks.com), AquaTech (http://www.aquatechtanks.com/sewage-storage-tanks), K.M.S. Plastworld (http://www.kmsplastworld.in/plastic-septic-tanks.html), and several others on IndiaMart

Figure 10 Innovations in septic tank design



which offer a turnkey solution to both primary and secondary treatment[5]. Therefore, local entrepreneurship may be encouraged for prefabrication of such technologies and the resulting systems accredited and promoted.

In bolstering innovation, sensors which predict system requirement for emptying and monitor its performance[6] at the household level can be developed. While a few of these products are available in more developed countries at a high price (USD 1000-2500 plus periodic maintenance cost), their design and fabrication could be modified to suit the local context with a reduction in the associated costs. The physical sensor, fitted in the tank and subsoil dispersion system, is usually linked to a digital dashboard via a mobile application through which homeowners can receive early warnings of system failure. Introducing such predictability into the OSS ecosystem coupled with the availability of ancillary service providers may serve to increase efficiency and safety of such systems.

5 International examples include the aforementioned Johkasou system, Taylex Tanks (Australia)

6 SepticSitter (https://septicsitter.com), Engineering Technologies Canada Ltd., Canada

If in the long term, the disposal of effluent from an advanced septic tank into a covered drain (possibly as one of a twin-drain system) emerges as the most feasible solution, effluent filters may be promoted. These filters, placed at the outlet of the tank, enhance solids removal (Byers, Zoeller, & Fletcher, 2001), thereby improving the effluent quality and reducing the possibility of drain choking. Future versions of the septic tank may benefit from a vertical panel, along the access road-facing wall of the septic tank (Figure 10). Given that a high proportion of tanks are built underneath existing structures, but with an outlet to the drain outside the premises, such a fixture may ease the process of tank emptying.

The individual applicability of these recommendations would have to assessed through the lens of local needs and a graded approach. Their strong potential to improve sanitation outcomes, associated costs, and ensuing systematic disruption would require further exploration.

b. Implementing Technical Standards

The technical standards require revision for enhancing their implementability and addressing evolving concerns. A quick review of the applicable standards reveals the nature and magnitude of the data required for building compliant OSS systems. Even if the information is available, it is compartmentalized and requires an integrated examination, not possible by either the households or the masons, given their limited expertise. Currently, the households and masons share the responsibility of decision-making, but neither of the two is equipped with the resources to ascertain a fully compliant system design for a given setting.

Furthermore, while the standards in their current form remain comprehensive in details of construction, they fail to prescribe the quality standard for the treated effluent. The absence of such a yardstick prohibits monitoring and quality control. Consequently, it also makes it difficult to hold an individual or agency accountable for system failure or to encourage innovation in the development of new systems. In the long term, instead of a broad-based quality standard, one accounting for local conditions could be developed – with stricter requirements for more sensitive regions.

At the same time, it would be critical to ensure that such flexibility is easily realized on the ground and does not come at the expense of clarity and implementability. For instance, the minimum allowable setback distance of groundwater sources from leaching pits varies based on the soil grade as well as the design of the pits. Achieving such a nuance at the household level may be difficult and thus lead to non-compliance. Therefore such revisions in the code for installation of OSS should remain user-friendly while eliminating any ambiguities regarding critical aspects, such as the setback distance.

c. Managing Tank Effluent

The treatment and safe disposal of tank effluent is a critical requirement of city-wide sanitation. The high density of OSS systems in Indian statutory towns constrains the possibility of retrofitting septic tanks with a subsoil dispersion system as a secondary treatment technology. Nevertheless, sparsely settled peripheral regions, which are often the last to be covered under centralized schemes, could still be considered for the construction of individual soak pits or dispersion trenches, should space, hydrogeology, and proximity to groundwater sources allow. However, it would be necessary to continually monitor the overall density of these systems to ensure that the collective leaching of partially treated effluent into the subsurface does not exceed the carrying capacity of the soil, as noted earlier.

In denser regions, a hybrid system such as the small-bore sewer or the twin-drain system may be designed (Figure 4) to convey the tank effluent off-site to a decentralized facility for secondary treatment before being released into the environment. The techno-economic success of such a model crucially depends upon its ability to adapt to a shifting catchment population (owing to urbanization, expansion of the city boundaries, or the introduction of a sewerage network).

Of the two, the small bore sewer may hold potential to replace city-wide centralised sewerage systems. During the planning for the latter, ULBs usually tend to take a greenfield approach. A small bore sewer with household-level tanks can reduce the requirement of materials and excavation, as well as, the stringency of wastewater flow requirements for sewerage development (CPHEEO, 2012). More importantly, such a system capitalizes on existing infrastructure for greater overall process efficiency, especially for smaller cities which are yet to introduce sewerage systems. However, due to the presence of both networked and non-networked components in the system design, the extant costs of emptying and treating septage would still accrue.

The treatment requirements of septage could be recognized at the planning stage, thus allowing for its co-treatment at the centralized wastewater treatment facility itself. Nevertheless, costs of evacuating and conveying the septage would be a key determinant of

Figure 11 *Variations in tank-based systems*

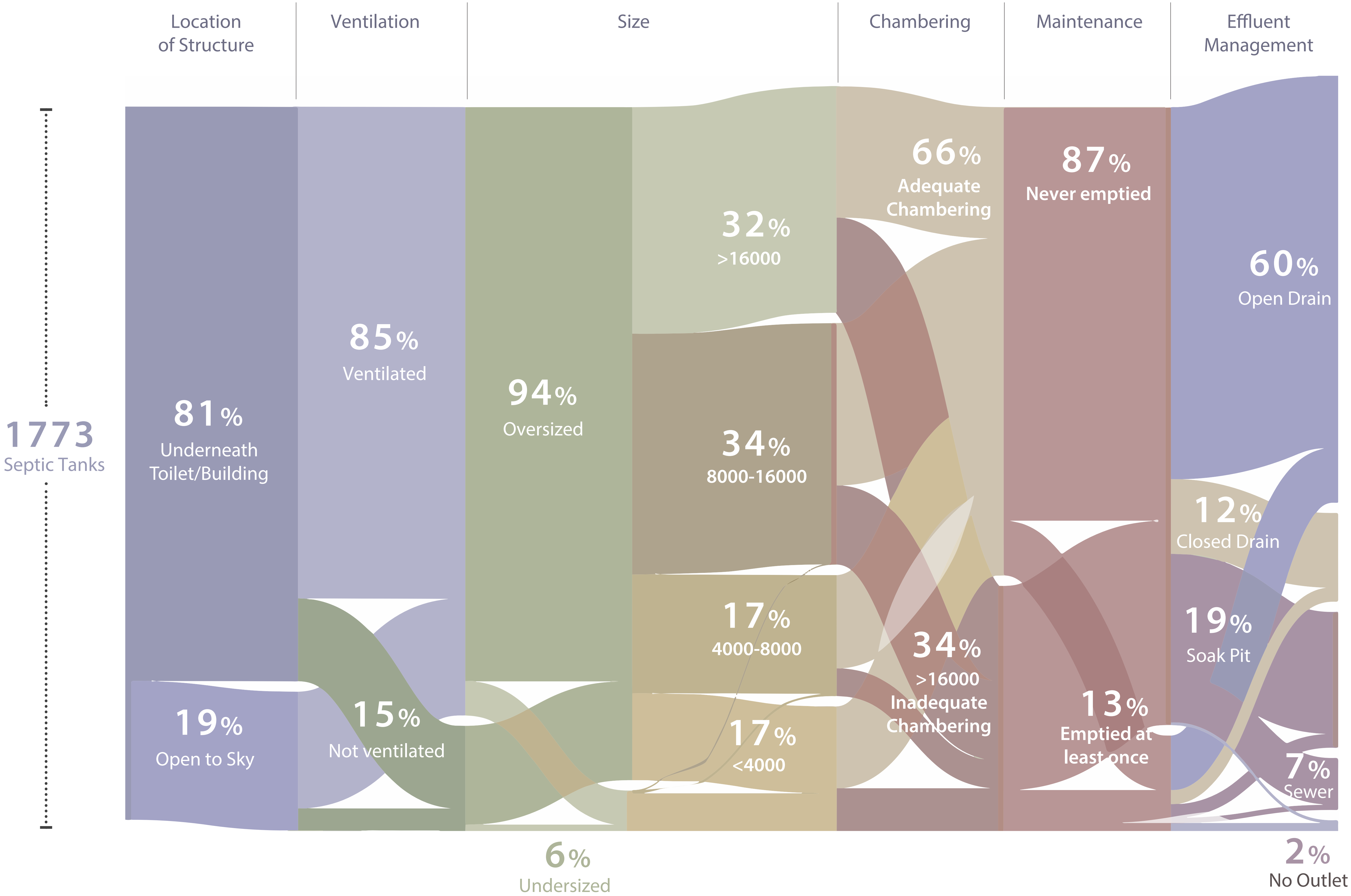
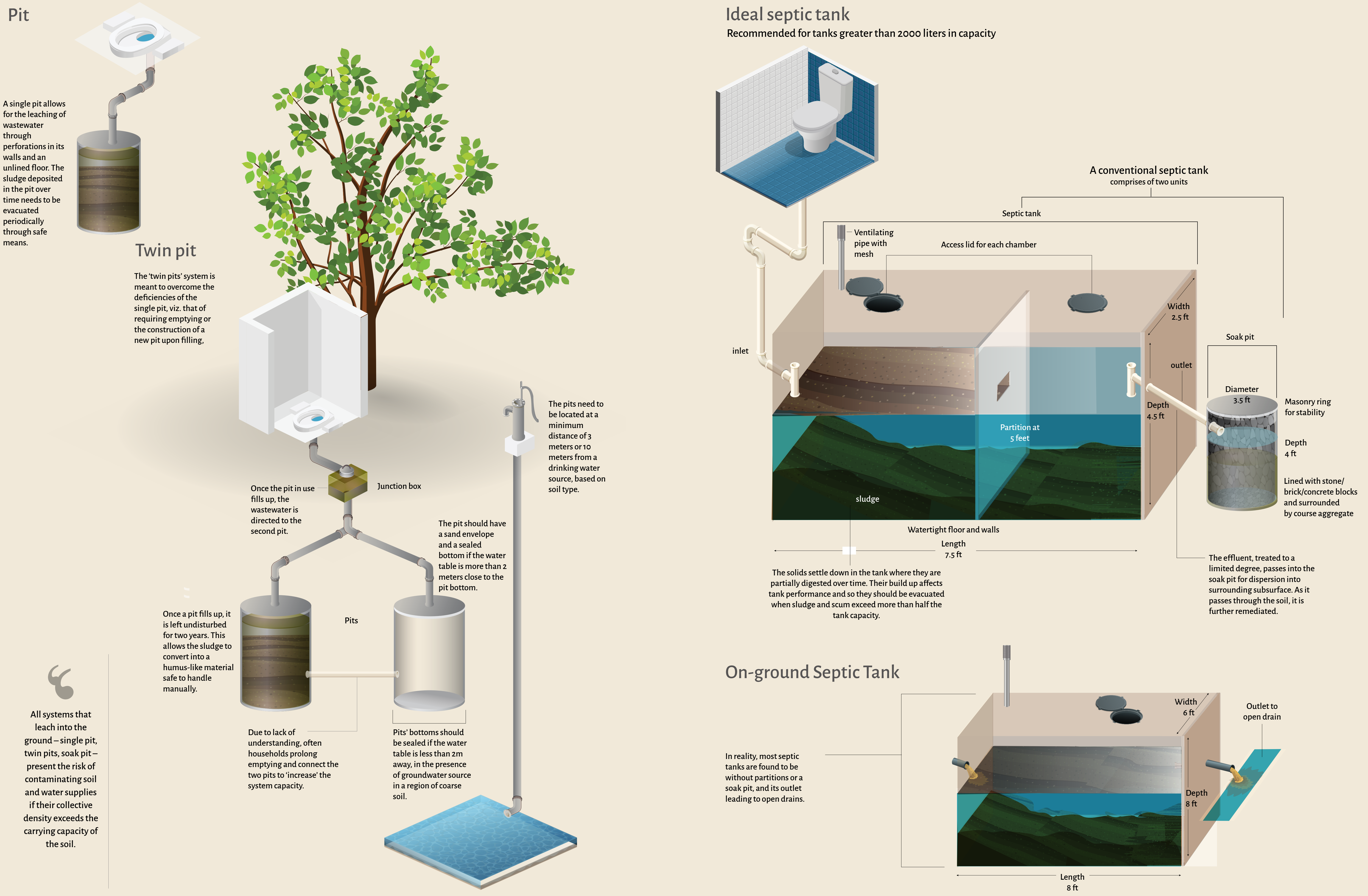


Figure 12 Ideal and on-ground configurations of OSS systems

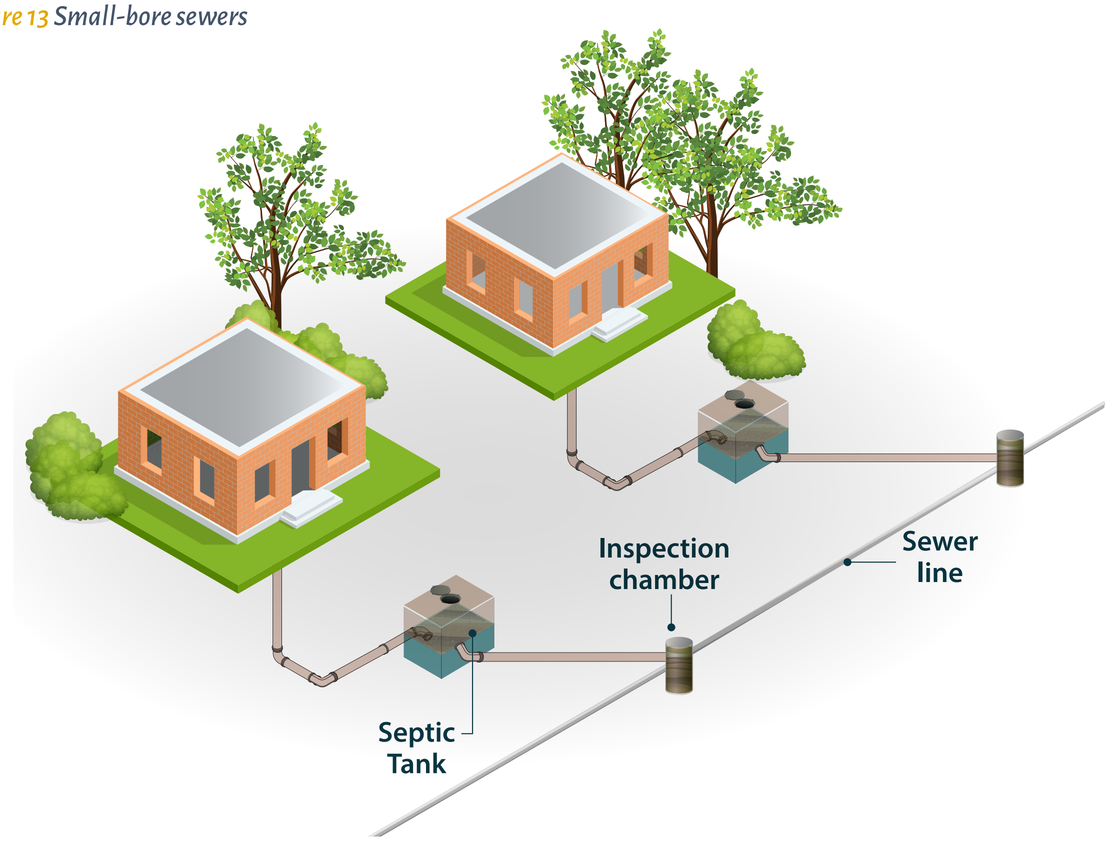


"All systems that leach into the ground – single pit, twin pits, soak pit – present the risk of contaminating soil and water supplies if their collective density exceeds the carrying capacity of the soil.

techno-economic feasibility of the hybrid system – not only from the perspective of the financial but also the environmental burden.

In the meanwhile, the existing drains could be covered to reduce the exposure of the communities to wastewater and prevent vector breeding. Such a measure must be deployed only for the short term as an interim solution lest it compromises the drain's primary function of stormwater management. The treatment and safe disposal of tank effluent is a critical requirement of city-wide sanitation.

Figure 13 Small-bore sewers



BOX 4 TRACING THE EVOLUTION OF ON-SITE SANITATION IN JAPAN AND MALAYSIA

Japan

With the slow growth of the centralized sewerage network and the poor performance of existing on-site facilities dealing with only blackwater, the pollution of water bodies was the impetus for the evolution of on-site sanitation in Japan. The Packaged Aerated Wastewater Treatment Plant (PAWTP) Act (Johkasou Act), 1983 underpinned the subsequent systematic interventions. The technology at the center of the legal and policy discourse, the PAWPT is an aerobic treatment system comprised of a septic tank for settling and anaerobic digestion of sludge in the first chamber and further remediation of effluent in an aerobic environment in the second chamber. The second chamber is packed with bio-film growth media for increased surface area and a blower for continuous dispersion of air.

The Act delineated the requirements for all key aspects of on-site facilities, viz. installation of manufactured OSS systems and their maintenance, inspection and emptying, as well as, the roles and responsibilities of various stakeholder, viz., users, municipalities, PAWTP operators, inspectors, and cesspool operators towards it. The cornerstones of the intervention, with their legal basis in the Act,

BOX 4 *CONTINUED*

were the introduction of regular emptying and the training and qualification of businesses/non-household users in installing, operating, or emptying PAWTPs or similar facilities. Early on, PAWTPs treating both black- and graywater were promoted through a national subsidy system. However, in 2000, the Act was amended to eliminate the use of only blackwater treating systems and mandate the installation of PAWTPs serving both blackwater and graywater management needs.

Any business intent on manufacturing PAWTPs must receive government approval. In turn, the homeowner or the building company acting on behalf of the homeowner must furnish details of PAWTP systems for receiving a building permit from the District Construction Surveyor. The owner of such a PWATP in a house or a building is then designated as the PAWTP Manager and is legally mandated to empty the PAWTP once a year through a 'PAWTP Desludging Vendor'. Sustained efforts towards institutionalizing reforms and a paradigm shift has resulted in a network of 2 million professionals engaged in the management of decentralized wastewater management systems (Hashimoto, 2019).

Malaysia

In-situ constructed septic tanks were popular till the early 1990s in Malaysia, but towards the end of the decade prefabricated systems gained popularity and began to achieve economies of scale. Until a few years ago when the Malaysian Sewerage Regulatory Body developed its own set of standards for prefab systems, regulators referred the Australia-New Zealand and Canadian standards for prefabricated systems composed of Glass Reinforced Plastic and Fiber Reinforced Plastic.

All new technology providers now must seek accreditation from the Department of Standards, Malaysia (DoSM) and upon receiving approval, register the product with the Sewerage Regulatory Body. Although prevailing technical guidelines provide for both the in-situ construction of systems and installation of prefabricated units, the former has been a rarity since the 2000s. The ULB has a minimal role to play in compliance at the household-level and households must seek approval from the Sewerage Regulatory Body for an OSS system's installation. In 2014, the system was further amended to reduce the involvement even of the Sewerage Regulatory Body by requiring households to hire professionals to oversee all matters of design, construction, and installation, and who are directly accountable to the Body in the event of non-compliance.

Currently, more than a dozen suppliers of prefabricated systems are available in the market, albeit differing minimally in technology. The most common configuration of the system is a tank with two compartments wherein the second compartment contains filter media such as course aggregate. Flexibility is offered not in terms of technology selection, but instead in sizes and costs (due to significant price competition). The systems are installed under the kitchen or in the background and tend to be compact to fit the usually small spaces. In-situ tanks follow a similar design but are larger and constructed using reinforced concrete. All on-site sanitation systems are registered, with the exception of those illegally installed, with precise details of system manufacturer, size, among others.

The effluent from these systems is disposed into covered drains overlaid with turf (drain up-gradation under the Urban Stormwater Management Manual for Malaysia, 2012). Effluent quality monitoring is not currently enforced in favour of scheduled desludging as a risk mitigation strategy. Since 1996, both blackwater and greywater are treated in the same system. In fact, the major changes occurring between the first half of the decade and the second may be attributed to the transference of sanitation-related responsibilities from ULBs to a federal regulator.

3 ADDRESSING UNIFICATION FOR ADAPTABILITY

The last chapter established that non-compliant tank-based systems form the vast majority of on-site sanitation systems. Oversizing of tanks, lack of partitioning, absence of effluent management, and inadequate maintenance constitute the primary deviations. In this chapter, the first three deviations are examined in relation to hydrogeological factors and socioeconomic characteristics, allowing the disaggregation of underlying dynamics of the choice and nature of system attributes.

Challenges

Masons do not account for groundwater and soil when determining system specifications in the way intended by the governing codes.

Plot size and Monthly Per Capita Expenditure (MPCE) are strong determinants of tank sizes, but pits are less susceptible to variations in household-level characteristics.

Groundwater sources exist in close proximity to on-site sanitation **systems in a significant proportion of cases.**

Opportunities

A formal portfolio of solutions – combining the household-level unit and downstream treatment requirements – can be developed for use by local-level planners.

Awareness-raising of households is a first step, followed by the adoption of a multi-pronged enforcement strategy.

Public services require bolstering in recognition of their nexus with the network of on-site sanitation systems.

WHAT WE FIND ON THE GROUND

The IS codes use regional hydrogeological attributes and the presence of groundwater sources as key determinants of the suitability of OSS systems but overlook the effects that the broader sanitation services ecosystem may have. Similarly, these standards take note that system sizing is dependent on household size but do not adequately account for other socioeconomic characteristics. Therefore, this section comprises three parts which collectively discuss the impact of environmental, socioeconomic, and services-related factors on the design of OSS systems. The impact of hydrogeology has been presented in the first part. In the second part, the relationship between household-level attributes and those of the system have been described. The third part describes the linkages between the nature of the system and the availability, or lack thereof, of public infrastructure and services.

a. Impact of Hydrogeology

The connection between the selection of technology and soil or terrain type is disjointedly perceived by masons. These factors are the most pertinent for determining the suitability and design of leaching systems. However, the study finds that masons consider the type of terrain as the only identifiable constraint since it directly contributes to the complexity of the construction process. In a 'difficult' setting, such as rocky substrata, masons report increasing the depth of the systems and the use of JCBs during construction. In one of the interviews, the soil type had also been linked to the structural integrity of the system but was never considered a determinant of system type – pit- or tank-based.

The significance of groundwater sources to the design and installation of OSS systems exhibited even lesser traction. The few masons who did recognize the issue could not correctly specify the setback requirement.

> 'Sometimes we see areas where labourers and hammers are not enough, and a JCB is required for digging. We can construct a septic tank in such an area, but for building a septic tank, the better soil is clay. If for some reason clay is not available, then any soil mixed with a poisonous medicine works. The poison ensures that the structure doesn't get attacked by termites or any other organism.'
>
> *– Mason from Dehradun*

> 'Because of lack of space, people don't care about the distance between tank and groundwater sources. A 20 feet deep tubewell always supplies water with odour, whereas, a 150 feet deep tubewell does not supply poor quality water.'
>
> *– Mason from Rudrapur*

Soil type is linked to variations in prevalence of pit-based systems, but their attributes are not impacted by depth to groundwater. The interviews with masons underscore the absence of hydrogeological

Figure 14 ***Prevalence of pit-based systems across different soil types***

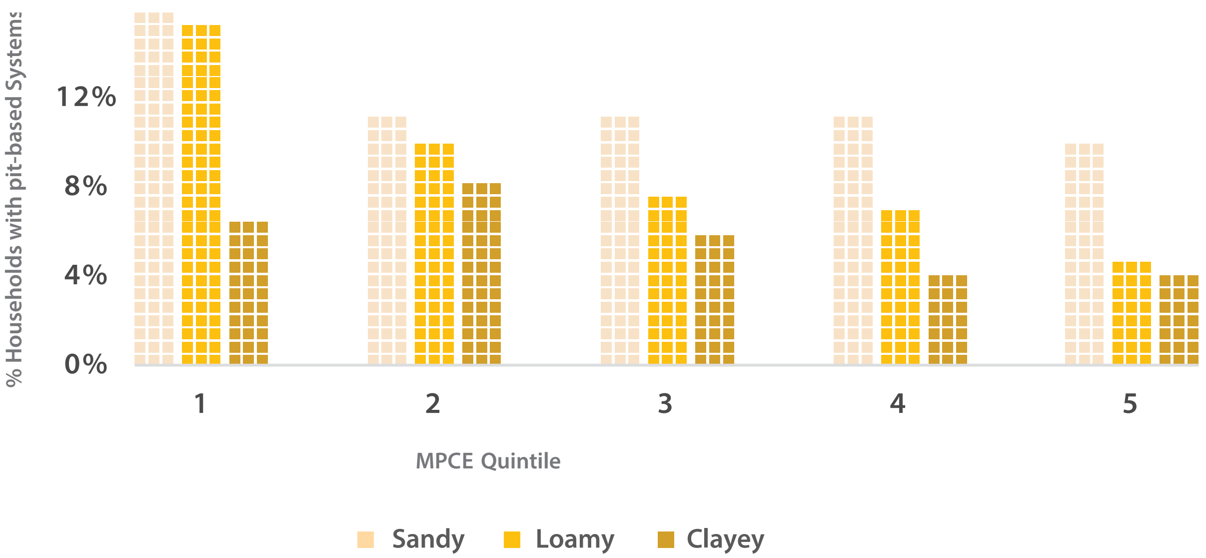
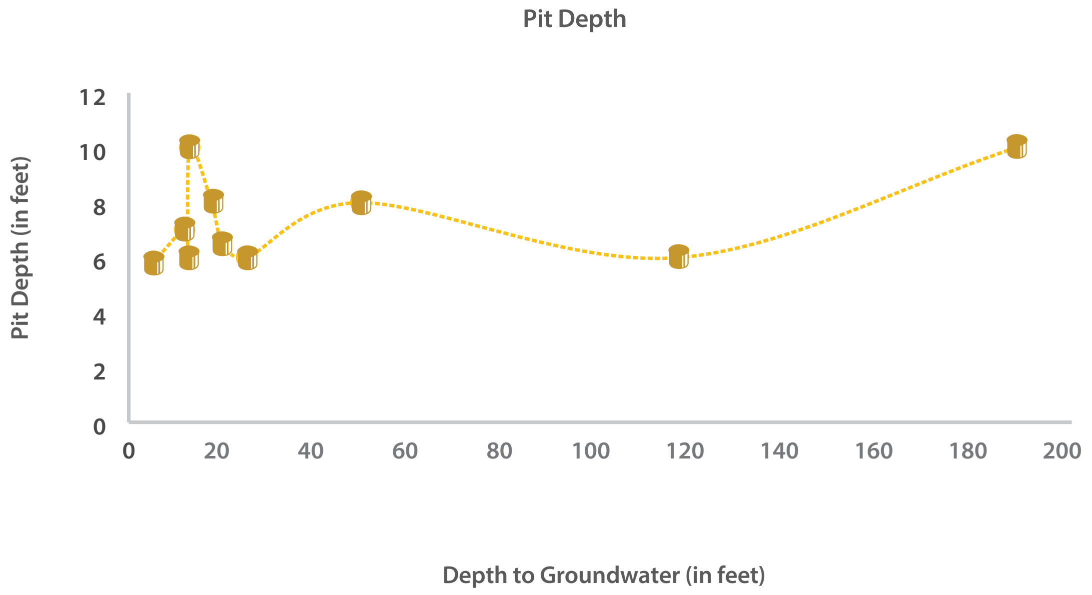


Figure 15 Variation in depth of pit-based systems with the depth to groundwater table



considerations for system design and safety. However, it is possible that constraints presented by specific settings effect implicit preferences over time. The data hints at such linkages with pit-based occurring in a lower proportion in regions with clayey soils compared to those with sandy and loamy soils (Figure 10).

On the other hand, the variations in depth of these leaching systems do not exhibit a trend with the depth to groundwater table or soil type (Figure 11). Further, pit design requirements posed by the IS code in specific hydrogeological settings remain unfulfilled in most cases as already noted in the previous chapter.

b. Impact of Household Attributes

Factors such as standard of living, caste, and education vary significantly across pit and tank owners. It was observed in Chapter 2 that pit-based systems are linked to subsidy-led IHHL construction and have doubled in the mix of sanitation technologies from 7.27% to 15.53% in the last five years. Accordingly, the data also shows that pit-based systems are significantly associated ($p<0.01$) with a lower standard of living[7], a lower monthly per capita expenditure, kutcha or semi-pucca housing, and smaller plot sizes on average. The difference in the mean per capita monthly expenditure between pit- and tank- households amounts to INR 416.

The likelihood of owning a pit-based system is linked with the caste of a given household. However, the association is not significant across different standards of living. Within the lowest quintile of wealth distribution, it is observed that these systems are more common among SC/ST households ($p<0.01$)compared to an OBC or a general caste. At the higher end of the MPCE distribution, the association with caste diminishes, and religion proves to be a stronger predictor of OSS type instead. In the top quintile, non-Hindu households were found to be showing higher ownership of pit-based systems ($p<0.01$).

Overall, within their category and like subsidy-led constructions, pit-based systems do not show significant variation with differences in household-level characteristics such as MPCE, plot size, type of dwelling unit, among others. In fact, being subsidy-led itself is a factor with a pronounced impact on the system size in both categories. The size of an OSS system which is wholly financed and constructed by households is nearly double that of one constructed through partial or complete use of public funds (Figure 13).

7 The Standard of Living Index (SLI) has been created in accordance with NFHS methodology. Based on the score households have been distributed among three quintiles as per NFHS-4 categorizations.

Figure 16 Average volume across system type for subsidy-led and privately constructed IHHLs

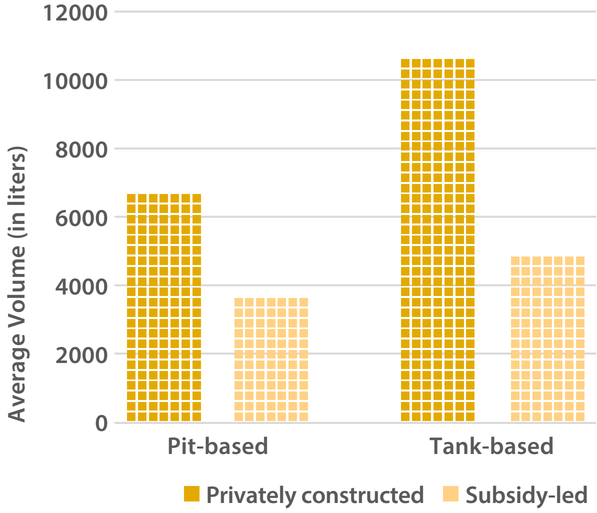


Table 4 Influence of household-level factors on tank sizes

Parameter	Category	Mean Size (In litres)
Plot Size***	Less than median plot size	11,470
	More than median plot size	14,835
MPCE***	Low and medium MPCE	11,444
	High MPCE	14,190
Type of Toilet***	Pour flush/dry toilet	12,855
	Cistern flush toilet	13,927
Category***	Non-general category	12,478
	General category	13,757
Type of Dwelling Unit***	Kutcha/semi-pucca house	11,450
	Pucca house	13,369
Age of System	System less than 5 years old	12,797
	System more than 5 years old	13,225
Household Size	5 or less HH members (small)	13,012
	More than 5 HH members (large)	13,295
Religion*	Non-Hindu household	12,108
	Hindu household	13,282

(evaluated through t-test analysis for privately constructed IHHLs with *,**,*** indicating significance at 10%, 5%, and 1% respectively)

The size of tank-based systems is influenced by with plot size and MPCE than by the size of the household. Unlike pit-based systems, the attributes of tank-based systems vary in response to changes in socioeconomic factors (Table 3). The data shows that the size of tank-based systems is strongly and positively associated with the plot size. The average septic tank size nearly doubles upon moving from the first to the top quintile of plot size distribution. Similarly, households in the top two consumption quintiles have a tank that is 24% larger on average than those in the bottom three.

On the other hand, the size of the households, a key input used for determining appropriate system size (Bureau of Indian Standards, 1985a, 1987), seems to not have a bearing on its size in reality. The average size of a tank per household size— ranging from 2 to 11—remains close to 13,000 liters.

Households with a cistern flush system, and presumably higher water usage in the toilet, also have bigger tanks than those with pour flush. Additionally, households residing in pucca dwelling units reported a tank that is 17% larger than those living in kutcha or semi-pucca housing.

Partitioning of tanks is associated both with larger than average tanks and a higher MPCE. Partitioning of tanks, is widely believed, to enhance system performance and the IS code deems a tank larger than 2,000 liters as requiring division into chambers. Partitioning of tanks is not dependent on whether the IHHL is subsidy-led or privately constructed, however the data shows that in both cases, the multi-chambered tanks are larger than those that are single-chambered. While the difference in mean MPCE among households with single-chambered and multi-chambered tanks is significant in the latter category, it is not in the former. A privately constructed multi-chambered tank is 15,800 liters on average, or 16% larger than the overall mean size and nearly eight times the threshold set by the code.

Interestingly, the state seems to be a strong differentiator between the prevalence of single- and multi-chambered tanks. The three cities of Odisha together report the three highest occurrences of multi-chambered tanks – possibly attributable to the regional nature of construction practices.

A septic tank with soak pit tends to be lower in volume than one without. The governing codes mandate secondary treatment of effluent from a septic tank, conventionally through soak pits or dispersion trenches. In the last chapter, it was observed that less than one-fifth of all the observed septic tanks meet this requirement. While the mean plot size does not significantly vary between those households that have constructed a soak pit and those that have not, the ratio of the built-up area to the plot size is lower for the former (Table 4). While utilizing a given parcel of land, the trade-off is inevitably between a soak pit and a larger septic tank, and as a result, households reporting a soak pit have smaller septic tanks on average. The difference, assuming a depth of 8 feet, amounts to nearly 10 square foot of extra space – sufficient area for a 3 feet wide cylindrical pit. Further, a cylindrical septic tank is more likely than a rectangular tank to be accompanied by a soak pit.

The water consumption for households with a soak pit tends to be lower, as also reflected in the fact that it is more common among pour flush toilets. Both the absence of drains and being subsidy-led seem to be associated with soak pits.

Table 5 Factors effecting the construction of a soak pit

Parameter	Mean Value	
	Without Soak Pit	With Soak Pit
LPCD (in litres)***	79	70
Tank Volume (in litres) ***	13,477	11,667
Built-up/Plot Area ratio**	0.91	0.89
Age of OSS (in years)	14	13
MPCE (in INR)	2408	2586
Plot Size (in sq. ft.)	1418	1329

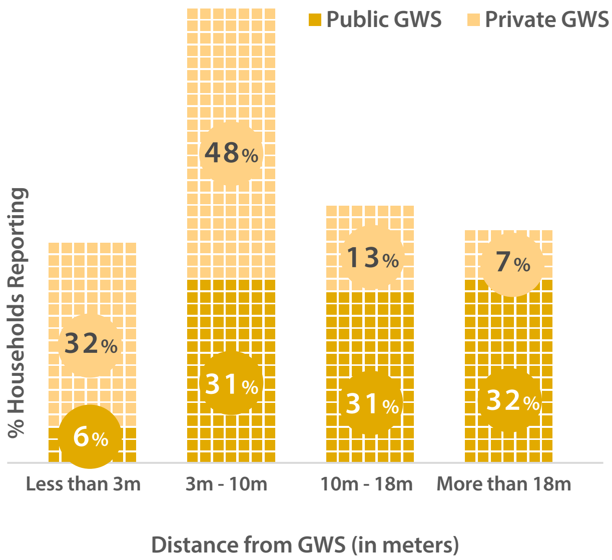
(evaluated through t-test analysis for privately constructed IHHLs with *,**,*** indicating significance at 10%, 5%, and 1% respectively)

c. Impact of Public Infrastructure

The proximity of OSS systems and groundwater sources may present a possible fecal-oral pathway. The study finds that 22% of the surveyed households rely simultaneously on OSS systems and groundwater sources (both public and privately owned) for the fulfillment of their potable water needs. The governing codes permit OSS system at a minimum lateral distance of 18 metres in the case of a soak pit or dispersion trench, and 3 meters and 10 meters respectively from a dry pit and a wet pit (Bureau of Indian Standards, 1985b, 1987). But, 87% of households dependent on a groundwater source for potable purposes report that it is horizontally located within 18 metres from their OSS system and 26% report that it is located horizontally within 3 metres, irrespective of whether the groundwater source is public or private. Overall, nearly two-thirds of these are situated in high to moderately high water table regions. 68% of the public groundwater sources situated within the nexus were found to be located within 18 metres from the OSS system of the surveyed household (Figure 6). Since sewerage access is spatially homogenous only at the ward-level within a city, these sources are likely to be used and surrounded by more such OSS-owning households with an implication for public health of the communities they serve.

While treatment of water before consumption is a crucial safeguard, 69% of all groundwater-reliant households consume water without any treatment. Households reporting a setback distance of less than 3 metres are at the highest risk, yet among this cohort, 72% of households do not treat water before consumption.

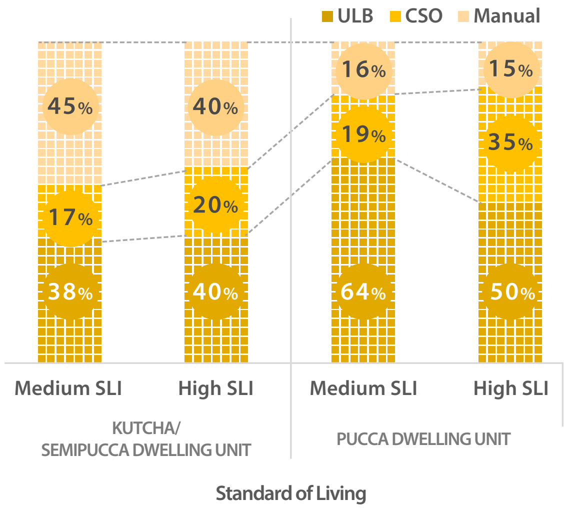
Figure 17 Setback distance of OSS systems from groundwater sources used for potable purposes



The socioeconomic status of a household moderates their access to emptying services. As the standard of living improves among those with a pucca house, the preference seems to shift towards private cesspool operators from public cesspool operators. Similarly, an increase in wealth causes a swing from manual cleaning to mechanized services among households residing in kutcha/semi-pucca dwelling units(Figure 9). However, the change in preference is more pronounced within the former category as compared to the latter – possibly due to lack of awareness and poor accessibility.

On average, the desludging fees charged by the ULB are lower than that of both privately provided mechanized and manual services. Most emptying requests were served promptly, although the proportion varied across different service provider types. Private cesspool operators and manual labor were able to cater to the demand on the same day in 79% and 67% of the cases, whereas this proportion for ULB cesspool vehicles lagged at 57%.

Figure 18 Choice of cesspool operators among households belonging to different socioeconomic categories



OPPORTUNITY

a. Diversifying Portfolio of Solutions

Options for OSS should reflect the diversity in the characteristics and needs presented by different households and settlement types. Across the socioeconomic spectrum, a considerable proportion of households rely on OSS systems in smaller cities of India. While septic tanks remain the most popular choice in OSS systems, a combination of factors such as the type of dwelling unit, the monthly per capita expenditure, size of the plot, and availability of services, among others determine the in situ deviations. Combined with the nature of settlement and its density, these engender differing levels of safety. For instance, concurrent reliance on leaching pits and 'potable' groundwater sources disproportionately affects the urban poor.

As a first step, OSS systems should be understood as part of a more holistic wastewater management scheme, keeping in mind that the type of household-level infrastructure has direct implications for treatment required downstream (in the absence of which public and environmental health issues may arise). Through an integrated approach, the techno-economic feasibility and social acceptability of such a scheme should be evaluated in its entirety (Figure 7). Thereby, the possibility of predetermining the suitability of one or more technological options for a given region should be explored, preferably at the state level. The State Pollution Control Board may act as a nodal agency for providing such technological guidance. Planners and engineers, at the local level, could create a technology selection matrix based on the considerations imposed by applicable codes, subdividing the city into zones, if required.

b. Introducing Awareness and Enforcement

Sensitization of households towards on-site sanitation, accompanied by a strong regulation framework, would encourage construction of compliant OSS systems. At the demand end of the sanitation infrastructure market, the households could be made aware of the importance of choosing and properly constructing an OSS system through information and education campaigns. The building inspection cell in a certain ULB in Madhya Pradesh retains a deposit of INR 7000-12,000 until the household has provided evidence for the construction of a rainwater harvesting system. Similar frameworks for incentivizing households towards compliant OSS systems could be devised.

While the periodic reinforcement of best practices may not be possible, the ULB may consider setting up 'Knowledge Resource Centres' (KRCs) at an intra-city level, through building capacity of existing community-level leadership such as ward councillors and Resident Welfare Associations (RWAs). These can serve as the household's first point of contact when faced with any concerns or queries regarding OSS. The KRCs could also be instrumental in directing the households to the appropriate service provider.

Awareness must be accompanied by the enforcement of regulations and monitoring of compliance. A multi-pronged strategy could be devised for the purpose, which includes both rewards (subsidies, tax waivers, awards, certification, among others) and penalties for non-compliance. Most importantly, the likelihood of non-compliant activity being detected and punished must be high for the enforcement mechanism to be effective (ISF-UTS and SNV, 2016). Therefore, a robust inspection plan would be a crucial factor in establishing its legitimacy.

c. Converging Public Sector Investment

The nexus between on-site sanitation and public services must be addressed for the true achievement of outcomes. Achieving total sanitation requires holistic planning and incremental infrastructural improvements as part of an iterative process. While the strides made under SBM may have ensured toilet access for a major part of the population previously not covered, the establishment of wastewater management systems and improvement of existing systems have not gained as much traction within the programme directives. The technological options for such a process discussed earlier, could be facilitated through the continuation of the programme or as a next phase.

Incentives could be rolled out for retrofitting OSS systems at the household level for the toilets constructed under SBM or otherwise. In regions where the density of the systems is high, even if planned retrofits or necessary setback distances to groundwater sources cannot be achieved (as is usually the case with slums and unauthorized colonies), a pit-based system could be converted to a tank, accompanied by a subsidized periodic evacuation of septage.

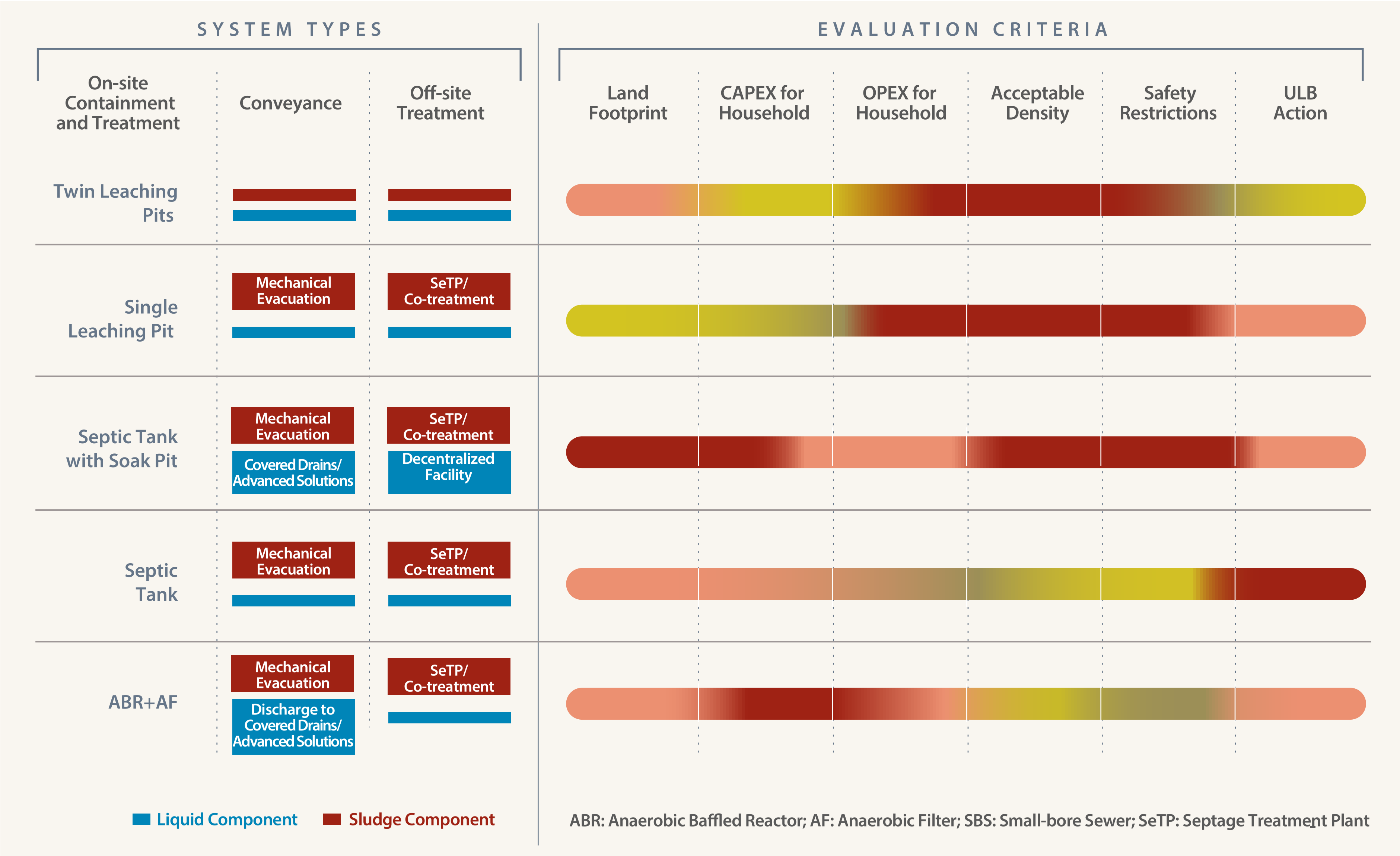
If a drain is available to the household, there is a significant chance that while planning their OSS system, the household would connect to it and thereby render their system unsafe. The stormwater drains could be concretized and covered for the following benefits:

- In the short-term, it would reduce exposure of communities to wastewater and vector breeding and attraction.
- In the long term, when alternatives have been designed and operationalized, it would prevent households from accessing the drainage system for the disposal of wastewater.

Measures to ensure safe drinking water supplies could be undertaken to counteract immediate public health risks while some of these technical improvements are planned and implemented. These could include, as a simple step, awareness generation about the need to treat water before consumption and making the methods and materials to do so available to low-income households.

Recognizing the signaling effect that the availability of efficient emptying services seems to have in influencing households to build smaller tank-based systems and the tendency of the households to utilize available space for larger tanks instead of effective treatment systems, the delivery of the service could be strengthened. Based on a demand assessment, the ULB could seek to enhance the capacity of cesspool vehicles and streamline the communication channels and processes entailed for quicker fulfilment of requests.

Figure 19 *A possible portfolio of solutions*



ABR: Anaerobic Baffled Reactor; AF: Anaerobic Filter; SBS: Small-bore Sewer; SeTP: Septage Treatment Plant

4 ADDRESSING COLLABORATION FOR SUSTAINABILITY

The second chapter of the present report laid down the typology of OSS systems and their deviations from the IS codes. Of these, the design-related deviations and those in availing services were analysed with respect to local factors in the third chapter. Building a successful sanitation service chain requires sustained coordination among several stakeholders, from the household to service providers such as masons and cesspool operators, local and regional entrepreneurs, as well as, regulators at multiple levels of administration. Accordingly, the present chapter examines the current scope of their participation across the sanitation service chain.

Challenges

Only 13% of all OSS systems reported emptying even once in their lifetime, being 13 years old on average.

Overall, ULB cesspool operators are the most commonly employed service providers, but manual cleaners were in 17% and 48% cases of tank and pit emptying, respectively.

Masons and households collaborate to construct OSS systems which won't require emptying, but subsidy-led constructions are relatively more regulated.

Opportunities

Timely emptying emerges as a middle-ground between on-demand and scheduled desludging based on a three-year schedule.

Masons as the purveyors of standardized systems and ULB officials as enforcers can collaborate systematically towards a new paradigm for OSS.

The creation of a city-wide database of OSS systems along with basic user and settlement-level information can go a long way towards regulation, monitoring, and future planning.

WHAT WE FIND ON THE GROUND

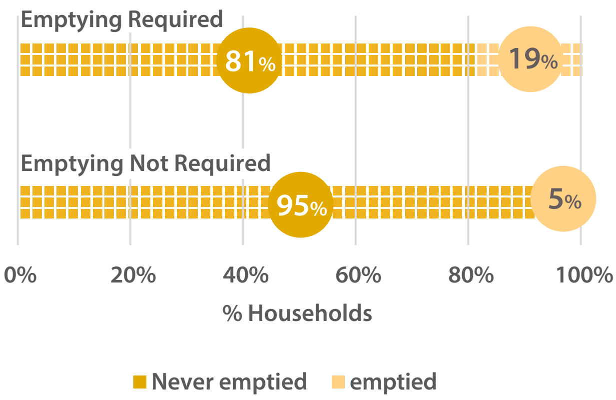
The design of an OSS system may dictate the maximum achievable efficiency of the system, but its maintenance through periodic desludging determines its performance over time. Therefore, it is important to understand not only the design understanding of masons, but also when and how safely households seek maintenance of a system. Accordingly, this section first analyses household-level behaviour towards system maintenance needs, followed by a discussion of the resulting process. The third part explores the perspective of masons and SBM-U contractors.

a. Maintenance Behaviours

Emptying of a system is a rare occurrence over its lifetime. As per the IS code, a septic tank should be emptied when the sum of the depth of the scum and the sludge is observed to exceed half the depth of the tank (Bureau of Indian Standards, 1985a). Accordingly, the code deems a half yearly or yearly desludging frequency desirable for the septic tank sizes it recommends[8]. Application of the underlying principle to the observed septic tanks reveals that only 19% of the tank requiring emptying had ever been emptied (Figure 8).

The need for desludging is triggered by 'visibly' extreme system failure. The study shows that across pit-based and tank-based systems, 65% of the households reported undertaking emptying as a response to an occurrence of choking and backflow of wastewater into the toilet. The remaining 35% claimed that desludging had been conducted as part of regular system maintenance. Accordingly, 13% of all households had undertaken maintenance of their system despite the average age of an OSS system being 13 years. Essentially, households continue to households continue to utilise their system past its ability to perform effectively, at the expense of the environment and surrounding communities.

Figure 20 Proportion of households reporting emptying their septic tank in view of its theoretical emptying requirement[10]



b. Ecosystem for Emptying

ULB is the most commonly engaged service provider for emptying of tanks, but manual cleaning is still prevalent. The data points out that 58% of tank-based systems had been emptied by ULB-owned cesspool vehicles and 25% by private cesspool vehicles. Overall, an OSS system had been manually emptied at least once in its lifetime in 26% of the cases, while 20% of the households reported engaging manual labour during the last incidence of desludging. In the state of Uttarakhand, none of the surveyed reported availing manual desludging services. On the other hand, nearly 30% of all emptying requests had been serviced manually in Madhya Pradesh and Odisha. The study finds that the phenomenon of manually cleaning is significantly associated with pit-based systems (Figure 9).

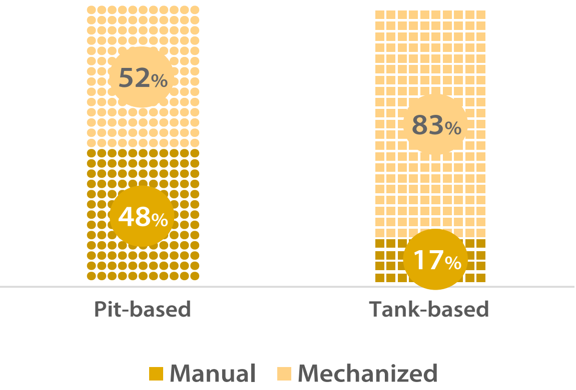
On average, the desludging fees charged by the ULB are lower than that of both privately provided mechanized and manual services. Private cesspool operators and manual labor were able to cater to the demand on the same day in 79% and 67% of the cases, whereas this proportion for ULB cesspool vehicles lagged at 57%.

Although nearly three-fourths of the households reported not facing any major issue during desludging, among those that did, the inability of cesspool vehicle to access the premises due to narrow lanes was the most commonly cited difficulty at 51%. Households also cited the lack of a lid for accessing the OSS system and sludge spillage during emptying as problems at 28% and 19% respectively.

Figure 21 Prevalence of manual cleaning by system type

8 As an example, the code recommends a ~1500 liters for five users, including the 300 mm freeboard and for a two-year desludging frequency.

9 Assumptions: Wastewater retention period - 48 hours; sludge build-up requiring emptying – 35% of tank volume (Bureau of Indian Standards, 1985a; Franceys, Pickford, & Reed, 1992) after accounting for wastewater retention.



Both public and private cesspool operators possess limited understanding of OSS systems. The interviews with operators indicated that they do not recognize the importance of leaving behind a fraction of the sludge to act as inoculum. Only due to technical constraints – 'the pipe doesn't pull all the sludge', 'the pipe cannot reach the sludge at the bottom', or 'it can only be emptied by hand' – is the sludge unintentionally left behind. In other cases, the operators claim to 'empty the tank fully'. Only in one case did the operator exhibit explicit intent.

> 'We leave around 3-4 inches of sludge because it will generate some bacteria.'
>
> *Private Cesspool Operator, Dehradun*

Untreated septage finds its way back to the environment due to a lack of FSSM infrastructure. Only in one of the ten surveyed cities, a site in the form of a sewer manhole had been designated for septage disposal. In all other cases, septage was being disposed at either a solid waste dumping site or a trenching ground in the case of public cesspool operators. Private service providers reported dumping the collected septage in drains, at vacant land, farmlands, and rivers.

c. Ecosystem for Construction

Subsidy-led construction of OSS systems was moderated by the preferences of SBM contractors and local ULB engineers. SBM contractors interviewed as part of the study maintained that designs decisions are based exclusively on norms provided by the government. Though lacking knowledge of the CPHEEO manual and guidelines, they had received a practical understanding of construction norms through discussion with ULB engineers or participation in SBM-related training sessions. In all but one of the cases, these ULB engineers were also reported to be monitoring the installation of the systems on the ground.

The contractors also stated that the beneficiary preferences for a certain technology (usually a septic tank) have little influence since the contractors believe that they 'do not have the permission to entertain such requests'. As per the contractors, households reportedly 'create nuisance about their preference', but seldom get their way in these cases. Despite the institutional stance adopted, contractors did seem to hold personal notions on appropriate system design for local conditions.

> "The pit system would be of no use after some time. The government should invest more money to aid construction of septic tanks of good quality which are more durable and can be connected to the sewer lines being laid down. If we have a septic tank, then we can directly connect the tank to sewer line, but with twin pits, we will have to connect the little box holding the knob to the sewer and then these pits would become useless."
>
> *- SBM Contractor from Sehore*

As to the maintenance of the pit-based system, contractors provided an emptying requirement ranging from two to six years.

Masons, although informally trained, adapt design of OSS systems to suit local requirements. None of the interviewed masons engaged in privately led construction were aware of the CPHEEO manual and had instead trained under the employment of contractors or through knowledge sharing with other masons. The dimensions of the last constructed septic tanks were reported as being 8 feet x 6 feet x 8 feet, 9 feet x 10 feet x 7 feet, 10 feet x 5 feet x 8 feet, 8 feet x 6 feet x 8 feet, and 8 feet x 8 feet x 9 feet. The interviews pointed out that an outlet to the drain is considered a norm, barring a few cases where soak pits are also accorded consideration and sewer lines where available are utilized for the management of tank effluent. The desludging requirement envisioned is upward of ten years, although in two cases, the masons believed that 'with an outlet' and 'proper flow of water' the tank never gets filled to the point of requiring emptying.

> "Earlier we used to build three chambers in a tank, but we don't anymore. Multiple chambers cost more and aren't very helpful while emptying the tank. It is easy to insert a pipe or for a person to enter a single-chambered septic tank.
>
> *- Mason from Rajsamand*

WHAT CAN BE DONE

Foregrounding ground realities within sanitation policy emerges as a compelling need. Building this local knowledge, developing policies that respond to local requirements and skilling service providers in their roles are all key opportunities. The first part of this section presents a new paradigm – "timely emptying" of OSS systems. The second part discusses skill building of service providers in convergence with other national programmes. The third part describes frameworks for monitoring and the requisite enabling environment.

a. Choosing between On-demand, Scheduled and Timely Emptying

The substantial variation observed in OSS systems demand a contextual approach to emptying practices over a rigid approach. In recent years, mandating a universal emptying frequency of three years has been gaining traction with policymakers and practitioners. However, this three-year schedule assumes broad-based compliance to the IS-recommended system sizes. Consequently, enforcing a standard, three-year frequency will compel households to incur the exact undue maintenance costs which they had sought to avoid by investing in larger containment units. More importantly, the process of methanogenesis-which takes around three years to be kickstarted - will be significantly hampered if the system is emptied at the proposed short intervals (D'Amato & Liehr, 2008).

Increased data availability raises the option of developing a more nuanced metric to calculate an appropriate emptying frequency, as opposed to an indiscriminate desludging timetable. Such a metric might take into account the number of users, wastewater flow rate, sludge accumulation rate, and the size of containment system (Figure 4).

Enforcement of a universal emptying frequency of three years has been gaining traction lately with policymakers and practitioners. However, it must be understood that the three-year schedule assumes broad-based compliance to the recommended system sizes. Consequently, enforcing such periodicity will mean compelling the households to incur undue maintenance costs against which they had sought to make a trade-off by investing in larger containment units. More importantly, the process of methanogenesis, which takes around three years to be kickstarted, will be hampered if the system is emptied at the proposed short intervals (D'Amato & Liehr, 2008).

Therefore, instead of introducing a high frequency emptying based on idealized conditions, ULBs could undertake an assessment of the appropriate emptying frequency, which takes into account the number of users, wastewater flow rate, sludge accumulation rate, and the size of containment system (Figure 4). Depending on the city-wide variance in the computed frequency, the ULB could adopt a more informed uniform frequency or a more flexible regime. Additionally, to ensure that sludge at the bottom of the system is not compacted to the point of requiring manual intervention in the case of very large tanks, a maximum emptying frequency should be decreed based on evidentiary research.

b. Building Stakeholders' Capacity

Masons can lead the efforts towards a new OSS paradigm. Repetitive practice has been one of the most important factors in the evolution of septic tank design (Winneberger, 1984). Limited knowledge of a system's operating principles results in masons adopting an ad hoc approach towards their design and construction. The repetition of these deviations - intended to fulfil

Figure 22 Estimated requirement of emptying for different number of users and tank sizes (refer Appendix II for detailed table)

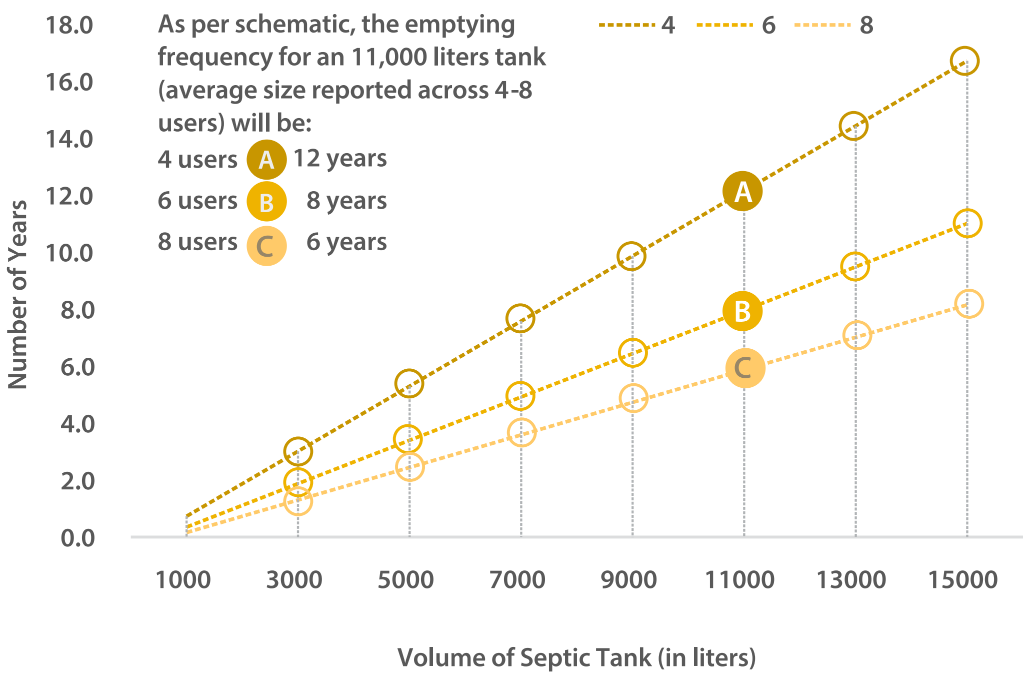
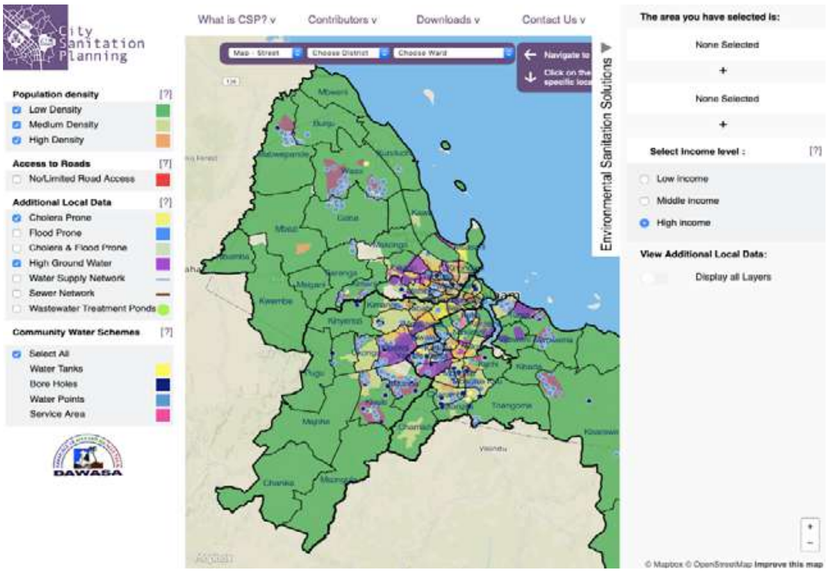


Figure 23 City Sanitation Planning tool for the city of Dar es Salaam (Source: http://citysanitationplanning.org)



household-level expectations – has continued over the years and geographies in the absence of external intervention. As has been observed, the resulting mutated system tends to clash with its inherent objective in most cases.

Masons are the first and only touchpoint to the household's requirement of on OSS system in the current paradigm, and therefore a critical point of intervention towards better systems. In fact, training and regulation of masons has the potential to be a quick-yielding cornerstone of any OSS improvement programme.

The ULB could undertake such an initiative in convergence with programmes such as Pradhan Mantri Kaushal Vikas Yojana (PMKVY) and the National Urban Livelihoods Mission (NULM). Upon building capacity, the ULB could license and empanel the trained masons for the construction of OSS systems. In an extension of their role, they could be tasked with registering key details of constructed systems with a local representative on a periodic basis.

c. Planning and Monitoring for Present and Future

Building robust local databases for on-site sanitation is critical in taking the national sanitation agenda forward. Many countries, like Ireland and France, have a relatively high rural reliance on OSS systems and have implemented extensive registration and monitoring protocols for residential septic tank systems.[10] There is scope for cities and states to learn from such examples. As part of the registration process, OSS systems can additionally be geotagged, utilizing and strengthening the existing SBM digital ecosystem, alongside groundwater sources. Such a database, if developed for the Indian context, could:

- serve as the basis for assessing the timely desludging requirement at the household level as per aforementioned matrix, and
- enable a holistic, data-based analysis to improve sanitation infrastructure while reducing prevalence of water and vector-borne diseases and improving quality of groundwater.

Going forward, OSS systems could be subject to periodic inspections. These inspections would feed into a metric for describing system performance that takes as inputs the influent and effluent characteristics. However, interviews with ULB officials showed that the implementation of multiple developmental programmes and their associated Management Information Systems (MIS) is shouldered by inadequately staffed and skilled ULB teams to the point of failure. As the key local actor, the ULB must be prioritized for capacity building – not only for post facto monitoring and data-management, but also strong and credible enforcement of provisions of extant building bye-laws. In view of the latter, a clear demarcation of responsibilities between the ULB and other stakeholders and creating strong accountability mechanisms to ensure their fulfilment will be crucial to the success of such a programme.

10 JMP reports that 30.3%, 18%, 11.8% of the total population relies on septic tanks and improved latrines in Ireland, United States of America, and France respectively.

CONCLUSION

OSS systems perform the critical role of containing and imparting treatment to fecal waste. The majority of the population in non-million plus cities depends on OSS systems, irrespective of city sizes, settlement densities and socioeconomic status. These are, however, widely considered an interim arrangement while cities – big and small – await an upgradation to the networked solution. This, together with their localized and private good nature poses a significant challenge towards ensuring their consistent quality and performance. All the decisions related to the design and maintenance of OSS systems, rest with the households which collaborate in varying degrees with informally trained masons for their installation. As a result, the pool of largely non-compliant systems, provide only inconsistent levels of safety and performance. Therefore, going forward, several interventions would be required to ensure that these systems perform adequately in the service chain of sustainable sanitation.

Such multi-pronged interventions, ought to address not only the physical system, but also the larger ecosystem within which they exist – including existing governing regulations viz. IS Code 2470 and 12314. In the years since the codes were first formulated, India has rapidly urbanized and densified without a commensurate expansion of the sewerage network and resultantly, embedded higher reliance on OSS systems. These systems, even when fully compliant, may continue to be unsuited to such dense urban settings – a significant safety aspect unrecognized thus far. Given that the IS codes have not been updated since they were first issued in the 1980s, they do not explicitly and adequately identify this as a constraint with a two-fold implication. First, it leads to the promotion and endorsement of technologies that may be unsuitable to urban environments, and second, it curbs innovations in technology design required to fill the gap. Regardless, systems on the ground, rarely comply with the technical standards in their present form, with less than 2% of OSS systems conforming to the governing codes. One of the fundamental reasons for this non-compliance is the lack of awareness among the masons towards the formal requirements for such systems. Consequently, in the popular imagination an OSS system is perceived as only a "containment" system, delinked from its objective of imparting "onsite treatment" of wastewater.

It is, therefore, not a surprise that households prefer to construct large systems – subject to the total availability of land and resources, paving and building over the system to maximize space utilization, wherever possible. The largeness of the tank-based systems may not be a glaring deviation if appropriate measures such as partitioning, ratios of dimensions, timely emptying – are adopted. In their noted absence, the majority of the tanks are just large, inefficient primary treatment units. In addition, the inadequately treated effluent from these tanks is discharged directly into the drains without further treatment, contributing to the pollution of downstream water bodies. The limited effectiveness due to design deficiencies can further diminish over time if the tank is not timely emptied. Although evacuation of fecal sludge accumulated in the tanks is crucial for performance control, households rely on visibly extreme system failure viz. choking and backflow, as an indicator of emptying requirement. Overall, in an analysis of the state of tank-based systems, 90% of all OSS systems emerge as dysfunctional.

Pit-based systems exhibit a similar variety of deviations. Twin pits had been principally designed to eliminate the need for external intervention by ensuring that the by-product viz. pit sludge is fully sanitized and safe to handle manually at the end of the treatment period. But, the prevalence of 'inter-connected' twin pits is grossly inconsistent with the technology's intended purpose. Furthermore, single pits are much more common than twin pits among pit-based systems. While the governing code deems single pits safe only if mechanically emptied, households avail manual cleaning in nearly half of all desludging instances. The cost of mechanized services, the dearth of availability and awareness thereof, issues with accessing the system for evacuation, or difficulty in pumping out pit sludge, more consolidated than septic tank sludge, may be inculcating such behavior.

On the whole, households largely employ both septic tanks and pits solely for blackwater management and graywater, alongside effluent, is disposed directly into drains. While not as pathogenically contaminated as blackwater, graywater being the major component of the domestic wastewater stream and containing chemical pollutants presents its own challenges and opportunities to be reckoned with.

The last five years witnessed an unprecedented national thrust on sanitation, articulated not only through policy but also a resource intensive mission-mode programme. The gains in toilet access achieved by the latter have been immense, but to realize the benefits of reduced open defecation, the waste collected and contained would have to be safely managed. In capitalizing on the household-level infrastructure developed under SBM-U, it would be imperative to address the lack of safety and compliance of newer, as well as, of older OSS systems.

The extent and inter-connectedness of the prevailing issues would require sustained political will, capital support, and the channeling of interventions through multiple points of entry, covering the spectrum of all existing and future stakeholders. Technical improvements in individual OSS systems are only a part of the solution, which also encompasses an overhaul of the relevant regulatory and governance mechanisms. The technical improvements themselves span a gamut - with some achievable in the short-term within the range of existing local and technological capabilities, and others demanding creation of the requisite enabling environment for their realization. Accordingly, a portfolio of interventions to tackle the complex and multifaceted issue ranging across design, planning and governance continuum is discussed below.

DESIGN

Train masons – Masons emerge as the crucial link between households and the technical standards. One of the ways to inculcate required design knowledge is by training them in the applicable protocols. Formally trained masons will also be able to lead the charge in mainstreaming enhanced versions of existing technologies, such as the ABR besides enabling the installation of compliant OSS systems. These efforts may be taken up in convergence with existing programmes like the National Urban Livelihood Mission and the National Skill Mission.

Empanel masons – Trained masons can be empaneled with the ULB for sustained engagement - leading to greater quality control over new constructions and efficient dissemination of sectoral developments.

Revise existing governing standards for OSS– Updating the governing standards to address contemporary concerns and greater implementability would remain critical. The revision should especially target the high prevalence of the systems in dense settings and their resultant proximity to groundwater sources, among others.

Specify performance standards – A major challenge in assessing system performance is the absence of a clear metric and benchmark. Specifying quality criteria for effluent offers a clear goal for households, regulators, and technology entrepreneurs to strive towards. For this purpose, the technical standards for system design may be linked to a graded standard for discharging effluent, flexible to the regional and environmental context.

Facilitate research and development – Recognition of the prevailing needs in urban sanitation entails the development of newer systems fit for the varied local contexts. Accordingly, entrepreneurship could be facilitated, dovetailing with existing programmes, for the development of newer OSS technologies at the household-level, as well as, models for effluent management. Adequate focus on R&D would be able to devise such facilities in the Indian context.

Mainstream modular, prefab alternatives – In assuring consistency in quality of new systems and retrofitting existing ones, prefabricated and modular packages can be a useful variant. These products may be mainstreamed through tie-ups with local sanitary marts, collaborating with masons, among others.

Develop standards and certification methods for modular systems – The Bureau of Indian Standards may aim to create manufacturing standards, aligned with international best practices[12], for the prefabricated systems to comply with. Such certification and ensuing formal quality control would not only promote standardization, but also inspire confidence in the technology among consumers for its uptake.

Undertake periodic inspection – OSS systems suffer not only from deviations in design, but also from inadequate maintenance. The ULB may seek to periodically inspect OSS systems to ascertain compliance and performance, a framework which may be modeled following international best practices. The monitoring should be combined with a mix of incentives and penalties to encourage households to comply.

PLANNING

Create data – Responsive planning is constrained by non-availability of meaningful local data on OSS systems. Accordingly, ULBs may seek to build data for planning and monitoring through either mandating households to register their OSS systems and/or undertaking a ULB census of OSS systems utilizing innovative tools like the Volaser.[13] The updation of the database may be ensured by sourcing information from masons and cesspool operators.

Design a timely emptying framework – At present, extreme system failure is usually the households' indicator for its emptying needs. The widespread use of a timely emptying framework may significantly be able to improve the effluent quality. Cities may adapt emptying frameworks on the basis of the dominant local OSS characteristics. These may include 'on-demand timely desludging' by providing appropriate information to households, a uniform period in the presence of uniform characteristics, or the adoption of a lowest common desludging period, to be devised based on the sizes of OSS systems in the city.

Manage effluent and graywater – In devising appropriate strategies, each city would have to account for the combination of ground realities, and challenges, as well as, intended environmental and public health outcomes. Based on the settlement type, availability of resources and the intervention horizon, ULBs would have to undertake micro-planning. As a measure for immediate relief, wastewater from drains may be intercepted and conveyed to a decentralized treatment facility and the drains themselves covered to reduce the possibility of vector-breeding. The measure must be adopted with caution, however, in consideration of the primary role of the drain as stormwater management infrastructure.

12 International Organization for Standardization (ISO) 30500; Bureau des Normalisation de Québec (BNQ) 3680-905
13 The Volaser is a recently developed (and field-tested in Sircilla, India) laser-based measuring device capable of determing the shape and dimensions of an on-site sanitation system. The device is also able to ascertain the fecal sludge depth in such a unit.

Ensure access to safe water supply – Island of settlements, even within cities with high access to piped water supply, concomitantly rely on OSS systems and groundwater sources. These communities are especially vulnerable to the groundwater-sanitation nexus and should be prioritized for provision of safer water supplies. Households should also be made aware about the importance of treating water prior to consumption in such circumstances and if required, means to do so should be supplied.

GOVERNANCE

Ensure mechanized emptying of OSS systems– Given, manual cleaning remains prevalent, especially among pit-based systems, eradication of such manual practices must be prioritized in the short-term. In order to achieve this, procurement of suitable mechanized technologies must be encouraged, whether through private provisions or public, for evacuation of sludge, especially for the pits. These services must be widely publicized, and may be subsidized for those belonging to urban poor households. These efforts should further be strengthened by focusing on reducing the time lag between the lodging of requests and their fulfillment.

Sensitize households – Households should be sensitized about the importance of constructing well-functioning OSS systems and their continued maintenance. This can be achieved through traditional IEC campaigns, along with newer channels, such as RWAs (as year-round knowledge resource centres), formally trained masons and cesspool operators.

Develop ULB capacity – ULB capacity and competency should be augmented to enable it to assume a stronger role going ahead in ensuring periodic monitoring of OSS systems. Along with undertaking trainings, states can institute a nodal agency to continually support and guide local actors in this regard.

Create accountability mechanisms – In their expanded role, ULB-level actors would emerge as the primary regulators of on-site sanitation systems, with support from other stakeholders. In order to strengthen such systematic collaboration, ULBs would need to engage with the key stakeholders to ensure a formal identification and allocation of roles along with provision of authority to fulfill these. This would also necessitate instituting mechanisms for accountability and grievance redressal.

Ensure continued allocation of earmarked resources - As a natural progression of the ongoing national programme, sustained funding should be secured to move beyond toilet access towards strengthening the downstream components of the sanitation service chain. Continued allocation of resources for the ensuing steps, especially, for retrofitting of existing OSS systems, effluent management, and research and development of novel OSS systems would be critical to achieve the broader public health outcomes.

Create operative guidelines – In monitoring the quality and performance of OSS systems, a simple yet standardized protocol may be developed at the National level to be adapted by local regulators and other service providers. Operative guidelines, among other aspects, should be able to serve as a guide for determining compliant system types for the local settings; inspect OSS system with regard to design and ascertaining the timely emptying requirement.

Institute structural reforms – The continuing lack of dedicated focus on OSS is also manifested in the absence of devoted roles within ULBs for their governance and regulation. Therefore, structural reforms for creating specific roles for the management of sanitation, particularly FSSM, infrastructure within the ULB ought to be instituted.

Moving ahead, a paradigm shift is required from treating these systems as 'private units' to viewing them as 'a network of localized wastewater management systems' with profound public health outcomes. Such a network may be treated at par with the centralized system, recognizing that despite their inherent differences, their ultimate goal and the scale are the same.

APPENDICES

APPENDIX 1: SITE SELECTION AND SAMPLING

1.1 Site selection

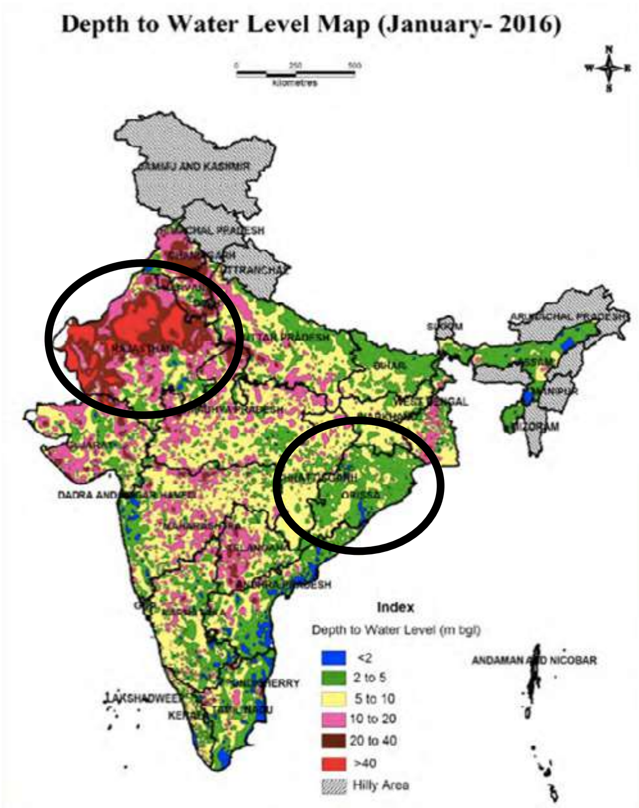
A total of 3000 households were surveyed across ten cities in four Indian states. The sites of enquiry were chosen through a multi stage inclusion criteria proceeding from state to district to city.

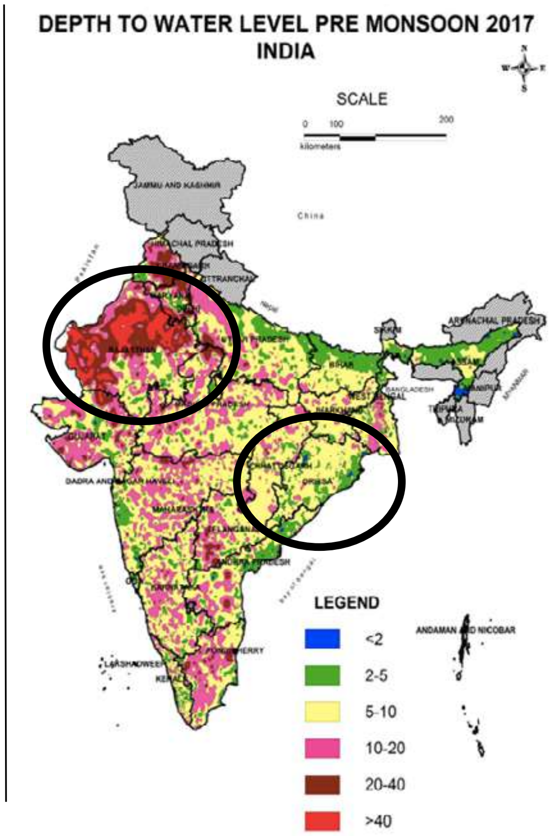
1.1.1 State Selection

- At the first stage, only those states whose OSS system relying proportions were greater than the national average were selected.
- Selected states were classified into high, intermediate, and low, to represent variability across the spectrum of depths to groundwater level (figure 2). The states of Odisha and Rajasthan, which have one of the highest and lowest depths to groundwater level respectively, have been selected thus.
- For states with intermediate and varying depths to groundwater level, a development index[14] and the extent of urbanization has been used to include states which exhibit trends in urbanization and development like Odisha and Rajasthan to have a common basis for comparison of findings.
- At the third stage, the two additional states of Madhya Pradesh and Uttarakhand have been selected to bring in diversity in terrain and soil type (figure 3).

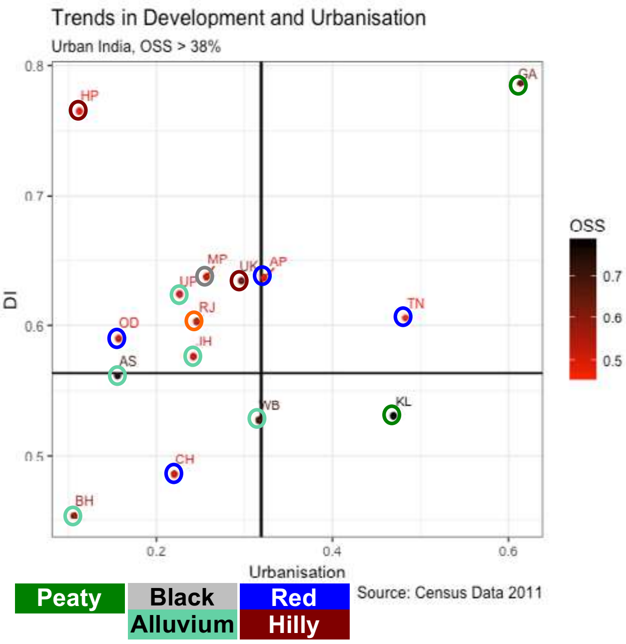
1.1.2. District Selection

- The reliance on OSS systems and groundwater sources in class I and class II cities in each district have been aggregated at the district level for each selected state.
- Between these four states, ten districts have been selected based on the proportion of households relying on OSS systems. Districts exhibiting high reliance on groundwater concomitant to high reliance on OSS systems present a special imperative for further enquiry and have





14 Composite of §access to electricity, access to water source within premises, access to treated tap water, access to closed drainage, access to improved kitchen fuel, ownership of motorized vehicle, and ownership of bank account.



been prioritized wherever possible. Overall, two to three districts have been selected per state along the spectrum of IHHL availability.

1.1.3. City Selection

- The highest urbanized city (district headquarter or otherwise), has been selected as the site of study in each district (figure 4).

1.2. Sampling strategy

- Within each city, ten wards were selected based on certain spatial inclusion criteria such as the presence of water bodies, highways and railway tracks, spatial distribution of the ward with respect to the core and periphery of the city. A total of 30 households were surveyed in each of the ten selected wards.

APPENDIX II: ESTIMATION OF SEPTIC TANK EMPTYING FREQUENCY (IN YEARS)

		Volume (in liters)							
		1000	3000	5000	7000	9000	11000	13000	15000
Number of Users	1	4.2	13.3	22.4	31.6	40.7	49.8	58.9	68.1
	2	1.9	6.4	11.0	15.6	20.1	24.7	29.3	33.8
	3	1.1	4.2	7.2	10.2	13.3	16.3	19.4	22.4
	4	0.7	3.0	5.3	7.6	9.9	12.1	14.4	16.7
	5	0.5	2.3	4.2	6.0	7.8	9.6	11.5	13.3
	6	0.4	1.9	3.4	4.9	6.4	8.0	9.5	11.0
	7	0.2	1.5	2.9	4.2	5.5	6.8	8.1	9.4
	8	0.2	1.3	2.4	3.6	4.7	5.9	7.0	8.2
	9	0.1	1.1	2.1	3.1	4.2	5.2	6.2	7.2
	10		1.0	1.9	2.8	3.7	4.6	5.5	6.4
	11		0.8	1.7	2.5	3.3	4.2	5.0	5.8
	12		0.7	1.5	2.3	3.0	3.8	4.5	5.3
	13		0.6	1.3	2.0	2.8	3.5	4.2	4.9
	14		0.6	1.2	1.9	2.5	3.2	3.8	4.5
	15		0.5	1.1	1.7	2.3	2.9	3.5	4.2
	16		0.4	1.0	1.6	2.2	2.7	3.3	3.9
	17		0.4	0.9	1.5	2.0	2.5	3.1	3.6
	18		0.4	0.9	1.4	1.9	2.4	2.9	3.4
	19		0.3	0.8	1.3	1.8	2.2	2.7	3.2
	20		0.3	0.7	1.2	1.6	2.1	2.6	3.0

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Scaling City Institutions for India: Sanitation

Sanitation programme at the Centre for Policy Research (CPR) is a multi-disciplinary research, outreach and policy support initiative. The programme seeks to improve the understanding of the reasons for poor sanitation, and to examine how these might be related to technology and service delivery models, institutions, governance and financial issues, and socio-economic dimensions. Based on research findings, it seeks to support national, state and city authorities develop policies and programmes for intervention with the goal of increasing access to inclusive, safe and sustainable sanitation. Initiated in 2013, the programme is primarily funded by the Bill and Melinda Gates Foundation (BMGF).

CENTRE FOR POLICY RESEARCH

SCI-FI SANITATION
SCALING CITY INSTITUTIONS FOR INDIA

DHARAM MARG, CHANAKYAPURI,
NEW DELHI – 110021. INDIA

Tel: +91 (11) 26115273-76 (4 LINES)

Fax: +91 (11) 26872746

Website: www.cprindia.org

Twitter @CPR_India and @CPR_SCIFI