Chapter

Managing Non-Sewered Sanitation for Achieving Sustainable Development Goal 6 in India

Shubhagato Dasgupta and Neha Agarwal

Abstract

The challenge of ensuring clean water and safely managed sanitation towards meeting the Sustainable Development Goal 6 is made more complex by unplanned urbanisation in South Asia. Nearly 50% of all toilet-owning households globally and 83% in South Asia depend on non-networked sanitation, with a multi-step service chain comprising containment, collection, conveyance, and treatment of faecal waste. Over the last few years, South Asian governments have begun to eschew the long-enduring preference for centralised sewerage infrastructure in favour of better management of non-networked sanitation as part of city-level wastewater management systems. However, these interventions have largely excluded the household-level containment systems that hold the potential to create both adverse localised and diffuse public health and environmental outcomes if dysfunctional. The present Chapter discusses evidence from a multi-state household survey in India to assess the nature and quality of containment systems in use by urban Indian households. Secondly, it reviews approaches to their governance under more evolved paradigms to inform an ecosystem-wide strategy for managing these systems in India and countries with similar contexts.

Keywords: sustainable sanitation, urban sanitation, on-site sanitation, non-networked sanitation, septic tanks, public health, prefabricated septic tanks, water pollution

1. Introduction: importance of non-networked sanitation to environmental and public health management

An extensive body of research underscores the importance of safe sanitation in reducing the incidence of waterborne diseases, maternal mortality rates, infant mortality rates, malnutrition, as well as, engendering individual well-being, productivity, and dignity. A lack of contextually designed and well-maintained sanitation systems at the level of the individual, settlements, and region, contribute to pollution of groundwater, waterways, soil, and lead to adverse public health outcomes [1, 2]. Yet, up until the last decade, the Global South has had to contend with a complete absence of basic sanitation facilities among large segments of the population leading to the practice of open defecation. At the turn of the millennium, 2.36 billion people globally practised open defecation or had access to an unimproved toilet facility, with a stark disparity in levels of sanitation between low and high income countries. As per the WHO-UNICEF Joint Monitoring Programme (JMP), seven out of every ten individuals in low-income countries lacked even basic sanitation in 2000. More broadly, 70% of the global population without access to basic sanitation resided in low- and lower-middle income countries.

The push to increase 'improved sanitation' at the level of the household under the Millennium Development Goals (MDGs) has since transformed to the Sustainable Development Goals' (SDG) focus on 'ensuring availability and sustainable management of water and sanitation for all'. While the former targeted the elimination of open defecation and the use of primitive facilities like bucket latrines, hanging toilets, pit latrines without slabs, latrines flowing into drains or the open environment, the latter reinstated the goal with the additional aims of increasing levels of wastewater management and reducing water pollution.

The increased attention to wastewater management in the wake of the SDG era has led to an improved understanding of the different approaches urban and rural households across the world adopt to manage faecal waste. In the preceding decades, vast sewerage networks conveying wastewater from the source to a centralised Sewage Treatment Plant (STP) had dominated the imagination of the city, state, and national governments alike. The last few years have witnessed an enduring recognition of how the sewerage system is unsuited to provide citywide sanitation as a universal gold standard [3]. Though the high population densities of bigger cities and metropolitans justify the cost of the networked solution to sanitation, given how fast many of the cities in the Global South have been growing, service delivery systems tend to fail in keeping pace and are left to play catch-up. Secondly, the low population densities of smaller cities, peri-urban areas, and rural settlements often do not justify the creation of sewerage systems, which are not only resource-intensive to construct, but also to operate and maintain.

By default, in the continuing absence of the networked sewerage system, improved and safe sanitation beyond the toilet takes the form of 'non-networked sanitation'. In its simplest definition, as per the International Organisation for Standardisation (ISO), non-networked sanitation comprises any sanitation system treating human excreta that operates without connection to any sewer or drainage network. According to the WHO-UNICEF JMP, in 2017, the number of people depending on non-networked sanitation is just as many as those served by sewerage systems at an approximate 3.1 billion. Unpacking the reliance on the two different types of systems across developmental regions shows that while the reliance on non-networked sanitation (in the form of septic tank, improved pit and other such systems) is much higher in low- and lower middle- income countries, it is not insignificant in upper middle- and high- income countries (**Figure 1**).

Non-networked systems take the form of septic tank systems, single pits, twin pits, composting toilets, container-based toilets, and newer varieties that convert faecal waste into fully treated liquid and solid end-products on site. Interestingly, both the conventional form of the septic tank system and the sewerage system emerged during the same period – the late 19th century - as alternatives to privies, cesspools and cesspits, that had led to disease outbreaks in rapidly-densifying European cities. The septic tank system, comprised of a watertight septic tank and a porous soak pit in series, was patented by John Mouras as the 'Mouras Automatic Scavenger' in France in 1881. The septic tank system soon landed on American shores, from where it spread widely as a low-cost technology for newly urbanising and low-density areas. Within decades, the failing systems spurred improvements in design and standardisation throughout the twentieth century. Guidance on best practices in the design of a septic tank system, known at the time as 'Typical Farm

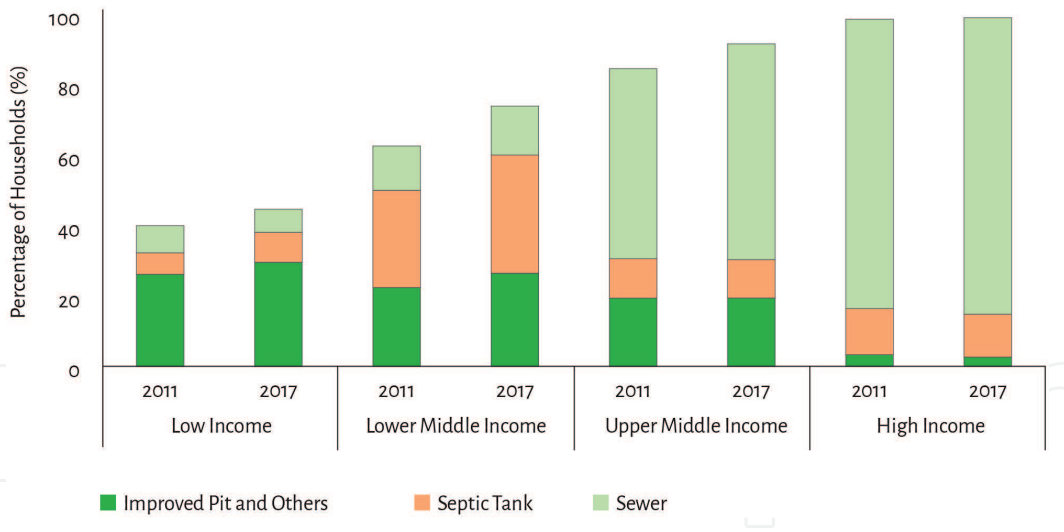

Figure 1.
Dependence on different types of sanitation systems.

Sewage Disposal System' was available in the 1920s in the USA. Formal standards also begin to emerge during this period, with the British Code of Practice first coming out in 1956 [4].

With the proliferation of the sewerage system across Europe, it began to grow in popularity as the standard model for sanitation in cities of the Global South as a result of colonial influence. As a counterpoint, the attempts to mainstream sewerage alternatives started in the 1970s with a World Bank research project that established that non-networked sanitation, or on-site sanitation, could offer a service to public health equivalent to the sewerage systems and at a lower cost. John Kalbermatten, leading the World Bank research, emphasised the importance of adopting a multi-technology strategy (sewered and non-sewered/on-site) in Urban Sanitation Planning to ensure universal coverage of adequate sanitation services [5].

Furthering this emerging unified discourse on sanitation, the United Nations declared the 1980s to be the 'International Water Supply and Sanitation Decade'. The declaration led to the formation of a Technical Advisory Group (TAG), comprised of the United Nations Development Programme (UNDP), World Bank, UNICEF, and members from the Government of India, in 1983, which recommended the 'twin-pit pour-flush latrine' as an appropriate low-cost sanitation solution for both rural and urban areas. Accordingly, the first Indian programme focused on sanitation, the Centrally Sponsored Rural Sanitation Programme (CSRSP), adopted the twin-pit system, a preference that continues in the latest national programme, the Swachh Bharat Mission (the Clean India Mission) [6].

The Group's 'Report of the Committee on Design Criteria for Pour-Flush Waterseal Latrines in Rural Communities of India' directly assisted the Bureau of Indian Standards (the national standard-setting body) in issuing the 'Code of Practice for Sanitation with Leaching Pits for Rural Communities' in 1988. The Code discusses various technical aspects of construction and maintenance of leaching pits and allows for both twin pits and the 'single pit', provided the latter is 'desludged by a vacuum tanker since its contents contain pathogen'. The Indian Code of Practice for Installation of Septic Tanks similarly discusses the design and construction criteria for septic tanks and subsoil dispersion systems in two separate parts first issued in 1963 and 1964 respectively, and significantly and substantively revised in 1985.

In the present time in India, as in other developing countries of the Global South, households construct the sanitation system, whether septic tanks or leaching pits, in situ. In contrast, developed countries that had targeted the issue of basic sanitation much earlier have created more mature ecosystems for non-networked sanitation. From the in situ construction of the systems driven by households, they have advanced to greater dependence on industrially manufactured and standardised on-site systems in a variety of materials like polyethylene and fibre-reinforced plastics, eschewing the traditional brick-and-mortar. Secondly, research and industrial innovation have led to newer on-site 'packaged' systems that perform the function of primary, secondary, and tertiary treatment in one compact unit. Thirdly, more than the unit itself, the regulatory and operative models governing non-networked sanitation and these systems have similarly evolved.

With the flagship governmental programme, Swachh Bharat Mission (SBM), segueing into its new phase, the national focus has shifted to challenges of managing faecal waste beyond the toilet. Both the urban and rural versions of SBM Phase II, announced in 2021 and 2020, respectively, mainstream Faecal Sludge Management (FSM), or the safe management of faecal sludge and septage evacuated from on-site systems as they fill up over time at an off-site facility, or a Faecal Sludge Treatment Plant (FSTP). While FSM solves the gaps in achieving safe and sustainable sanitation beyond the individual premises and is critical, a sole focus on FSM often excludes the discussion on the quality of on-site systems and its improvement from the agenda. With investments in sanitation continuing to intensify as we enter the last decade of the SDG era, it is important to evaluate the need for systematic improvement in the on-site infrastructure for ensuring that the entire service chain of sanitation is secure. The issue is only underscored by a growing institutional acceptance of the on-ground common knowledge that on-site systems do not comply with basic safety standards [6, 7].

The present paper reviews the findings of a novel sample survey focused on on-site systems administered to 3,000 households across urban India. It offers insights on the typology and compliance status of these systems and how learning from advanced contexts, the whole ecosystem for non-networked sanitation can evolve in India and similar contexts across the Global South.

2. Unearthing facts of On-Site Systems (OSS) in urban India

The global sanitation agenda has mainstreamed the importance of on-site systems and FSM in achieving safely managed sanitation in urban and rural areas alike in the Global South. The newfound recognition of non-networked sanitation as a viable and necessary alternative to sewerage systems led the Ministry of Housing and Urban Affairs (MoHUA), Government of India, to issue the National Policy on Faecal Sludge and Septage Management, 2017. The Policy has created an imperative at the national level for the implementation of FSM and set out the necessary priorities and directions for the states. It introduces the sanitation service chain as a framework for understanding the issues of non-networked sanitation, and while it does go over the importance of ensuring that on-site systems are compliant, no governmental programme for their improvement has stemmed from it so far.

Without detailed data on the exact nature of deviations and what requirements households are trying to solve for in adopting certain preferences in design, a responsive and comprehensive strategy for improving the quality of on-site systems cannot emerge. The general view of non-compliance of on-site systems derives directly from the poor application of building regulations overall in Indian cities [8]. Building regulations despite their stringent provisions for enforcement are violated in India due to low awareness of households regarding their importance, a laggard upgradation of rules and systems when compared to the ever-evolving ground realities, and perhaps most critically, the weak capacity of local authorities in enforcing the regulations.

The National Sample Survey 76th Round (administered by the Ministry of Statistics and Programme Implementation), 2018, asked households how often they desludge their on-site systems and for related details viz. service provider, place of disposal, service charges. It was the first time that recurring nation data collection efforts had articulated such questions, with the Census of India and the preceding rounds of the National Sample Survey only asking about which type of on-site system the toilet has. Still, the framing of these questions is rooted more in understanding the need for FSM than in defining the attributes of on-site systems in and of themselves. As the following sections will show, the timely desludging of faecal sludge and septage from these systems and its safe management downstream is critical, but it is a recurring event that does not inherently fix all the issues in the system's day-to-day and year-round performance.

To plug the gap in the data available on on-site systems and the agenda for their improvement, the authors' conducted a novel multi-state survey of 3,000 households across urban India. The survey focused its attention on cities and towns with a population of less than 1,000,000, given that these are the ones that, given the trajectory of sewerage system development, would continue to depend on non-networked sanitation in the medium to long term. Since typically hydrogeological factors such as the depth to the groundwater table, terrain, and soil type are contributing factors in determining the most suitable design of an on-site system, the 3,000 households were spread out over the four hydrogeologically diverse states of Madhya Pradesh (plains, moderate water table), Rajasthan (desert soils, low water table) Odisha (coastal, high water table), and Uttarakhand (hilly, moderate to low water table). The sampling design ultimately selected a total of ten cities in these four states as sites of enquiry. Structured interviews with masons, public health engineers/sanitation inspectors, and desludging service providers accompanied the household survey to allow for the triangulation and better contextualisation of the survey findings [9].

The following sub-sections discuss the main findings of the survey and their implications.

2.1 Higher dependence on septic tanks compared to leaching pits

As seen earlier, the need for the invention of the septic tank system was rooted in a desire for improving the cesspits, cesspools, and privies prevalent during the latter half of the nineteenth century. The leaching of contaminants to the subsurface in the high-density areas typical of burgeoning cities and a limited network of piped water supply combine to create disease outbreaks like the Broad Street Cholera Outbreak of 1854 in London [10]. While the unimproved systems of the time were eschewed for sewerage systems and septic tank systems in the Global North the discourse in the Global South stayed stagnated on (a) sewerage systems as the sanitation standard to aspire to and (b) twin pits as the government's preferred low-cost technological options in its absence, the latter as recently as the ongoing SBM Phase II.

Nonetheless, the data notes that nine out of ten toilet-owning households in these cities depend on a septic tank. It is important to note at this juncture that the authors' use of the phrase 'septic tank' is intentional since the majority of households construct the septic tank system only partially, i.e. construct the septic tank, which serves as the primary treatment unit, without constructing second component for secondary treatment or safe disposal of the tank effluent. The clear preference for septic tanks in urban areas is evinced by the fact that leaching pits are significantly associated ($p < 0.01$) with a lower standard of living, a lower monthly per capita expenditure, semi-permanent or temporary housing, and smaller plot sizes on average. In other words, between septic tanks and leaching pits, urban households view the former as the better option, and the construction of the latter is more a function of capital constraints than an informed preference. Another way the phenomenon manifests is when the prevalence of the two main types of on-site systems is disaggregated by whether the households constructed the toilet on their own ('privately constructed') or under a government programme ('subsidy led'). The share of leaching pits rises a little over three times among toilets constructed under the government programme (**Figure 2**).

The de facto and widespread preference for septic tanks, emerging without a governmental boost, already means that urban India is at an intermediate point in the trajectory towards mature ecosystems for non-networked sanitation. The relatively low prevalence of leaching pits at the city level may have staved off acute incidences of waterborne diseases, but as the following sections show, more ground needs covering before Indian cities have well-functioning sanitation service chains from the toilet to treatment.

2.2 Critical absence of secondary treatment of effluent and poor primary treatment to begin with

Many factors influence the performance of a septic tank as a primary treatment unit, and none of them preclude the necessity of a secondary component for the management of the effluent that a septic tank releases. The septic tank does not act on pathogens and stabilises the settled solids, or sludge, to an extent (a reduction of 30–50% in the Biochemical Oxygen Demand (BOD) and up to 50% in that of Total Suspended Solids (TSS) can be expected). Tweaking the design of the basic septic tank – whether big or small, with or without partitions, with wide or narrow channels, shallow or deep, can increase or decrease the primary treatment efficiency, i.e. the ability to separate liquids and solids and effect partial digestion of stored solids over time. But, no matter how perfect the primary treatment, the effluent from a septic tank needs further treatment due to the significant remnant pollution load (**Table 1**).

The Indian Code of Practice recognises the distinction between a 'septic tank' and a 'septic tank system' too and declares that 'under no circumstances should effluent from a septic tank be allowed into an open channel drain or body of water without adequate treatment'. The survey data shows that 72% of septic tanks discharge the tank effluent into drains designed for stormwater management. In 60% of the cases, the drains are uncovered and exposed to the environment, while in 12%, the drains have a covering. Related research investigating

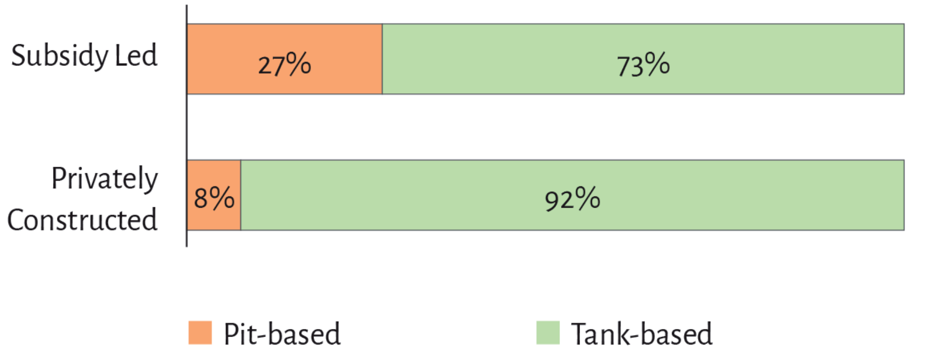

Figure 2.
Type of on-site system based on financing of toilet construction.

Parameter	Average Septic Tank Effluent Characteristics	Standard for Wastewater Treatment per Notification issued by Ministry of Forests, Environment, and Climate Change (MoEFCC), 2017		Proposed Standard for Wastewater Treatment as per National Green Tribunal, 2019 (for mega and metropolitan cities)
		Metro cities and state capitals	**All other regions**	
Biochemical Oxygen Demand (mg/l)	**203**	20	30	10
Chemical Oxygen Demand (mg/l)	**619**			50
Total Suspended Solids (mg/l)	**2377**	50	100	20
Total Kjeldahl Nitrogen (mg/l)	**318**			10
Dissolved Phosphorous (mg/l)				1
pH	**6.69**	6.5–9	6.5–9	
Faecal Coliform (Most Probable Number per 100 ml)	**1.63x10^7 Colony Forming Units per 100 ml**	1000	1000	230

***Authors' study based on a sample of 32 septic tanks in Udaipur, Rajasthan.*

Table 1.
Characteristics of septic tank effluent and standards for wastewater treatment.

the epidemiological impact of this phenomenon in peri-urban areas of Bolivia has related it to an increased incidence of diarrhoea in children under age five. It cautions against the poor quality and mismanagement of tank effluent attenuating the gains from increased access to toilets and improved on-site sanitation systems [11].

Just as significantly, greywater, or wastewater from activities such as washing, bathing, and other non-toilet related purposes, produced by the households too ends up in these drains, with 92% of all on-site systems being receiving only blackwater as input. Only 8% of the households reported treating the greywater in the same on-site system as the one for their blackwater or a separate one. Although greywater is minimally pathogenic compared to blackwater, it still contains pollutants and microcontaminants from residual pharmaceuticals, personal care products, aerosols, pigments, and other such products. Due to a lack of interception of the drains and treatment of waste flows, the disposal of tank effluent and greywater into drains holds the potential to not only cause adverse outcomes in health at source but also serve as a diffuse source of water pollution.

2.3 Household preference for septic tanks that are an order of magnitude larger than the recommended size

The issuing of the National Policy on Faecal Sludge and Septage Management, 2017, unlocked investments for the creation of city-level FSM infrastructure and assets. The Policy arrived two years into the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), a massive urban infrastructure development programme with a total outlay of INR 77,640 crores (USD ~10.41 billion) covering 500 of the country's largest cities. The programme allocated 95% of its outlay towards water supply, wastewater management, and drainage. However, at its inception, AMRUT did not feature FSM as a component of wastewater management. Due to the National Policy and continuing advocacy on the importance of FSM to achieve citywide sanitation, AMRUT recognised and incorporated FSM as an investment area in its purview. Now, in 2021, the Covid-19 pandemic has emerged as the new foreground for reinvigorated investments in water supply and wastewater management. In India, MoHUA announced the second phase of SBM (2021–2026), which promotes FSM as a wastewater management solution for all cities with a population of less than 1,00,000.

The increased influx of national investments would bolster the smooth scaling up of FSM already underway in the country – going from standalone pilots 2015 onward to scale-up of FSM in AMRUT cities and further across all cities and towns in states like Maharashtra and Odisha that have been early champions of FSM. These investments usually mean setting up FSTPs in the city and acquiring vacuum trucks to desludge the on-site systems and convey faecal sludge to the FSTP(s). Though the capacity of local governments – big and small - to provide mechanised desludging services is on the rise, the engagement of informal and small-scale service providers, including manual labour, for desludging continues to be a reality of the non-networked sanitation ecosystem in India.

Owing to the pernicious entrenchment of sanitation-work within caste-based social hierarchies in India, the national government had notified 'The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act' in 2013. The Act does not disallow per se the engagement of manual labour for desludging provided they adopt the prescribed safety equipment and protocols. However, largely, the engagement of manual labour takes the form of 'hazardous cleaning' or the manual cleaning of a septic tank without the prescribed protective gear, cleaning equipment, and safety precautions, which the Act deems a criminal offence [12]. More generally, the traditional norms of purity and pollution too have shaped the sanitation practices in India, with a significant body of research finding that these notions impact whether or not a household chooses to own and use a toilet facility [13, 14].

Within this context, the authors' survey finds that both households and masons consider an on-site system that does not require frequent maintenance, and thus engagement with the system, the gold standard in design. One of the masons interviewed as part of the primary data collection reported with confidence that the last septic tank he constructed would not require emptying for the next 40–50 years. Another mason acknowledged that with the large sizes of the tanks and a small number of users, the tanks would take 25–30 years to fill up. Overall, in the perception of both the households and the masons, on-site systems appear to be largely divorced from their role as a treatment system and are instead viewed as a mere containment structure that should be able to store faecal waste for as long as possible. Accordingly, while the Indian Code of Practice recommends a septic tank size of ~1,100 litres for five users, the average size of the septic tank for the same number of users is ~11,000 litres, as reported on the ground. The size shows a clear relationship with the economic status of the household, but not the size of the household as theory and the technical standard would dictate (**Figure 3**).

Along with the household's economic status, the lot size of the dwelling presents a physical constraint to the size of the septic tank and is positively associated with it. The third factor which strongly associates with the septic tank size, albeit

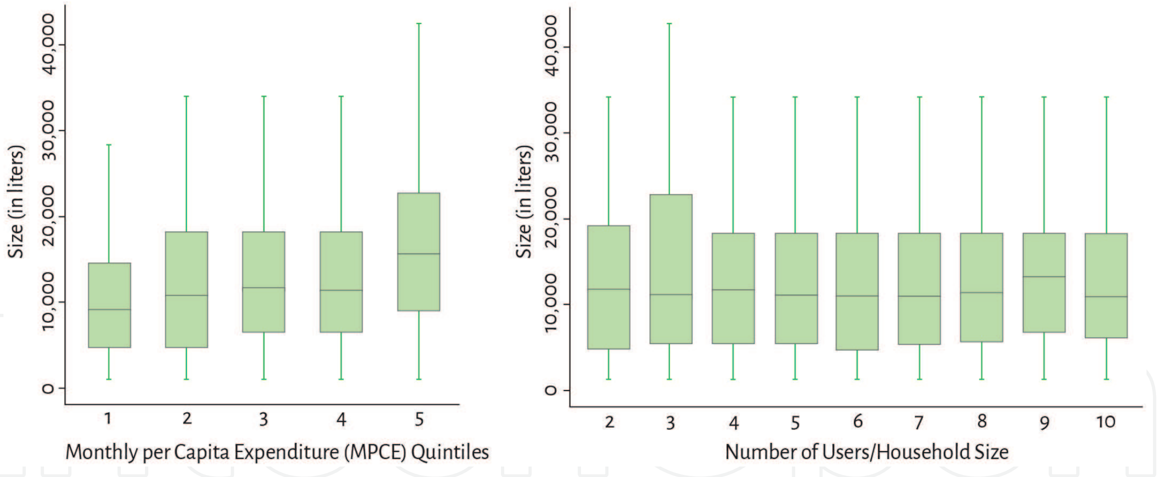

Figure 3.
Variation in septic tank sizes with respect to monthly per capita expenditure (MPCE) and number of users.

negatively, is whether the household constructed the toilet on their own or with support from the government programme. In the case of the latter, the average reported size of the septic tank dropped down by 50% to ~5,620 litres. Winneberger remarked, "Modern septic tank design has evolved mostly as a function of construction convenience, low cost, and repetitive practice" about the evolution of septic tank design in 1984 [15]. As it holds, his remark bears insight into the deviations constituting contemporary construction practices and the phenomenon of the household's preference for large septic tank sizes too.

2.4 Desludging frequencies running into decades due to large sizes

Like any wastewater management system, on-site systems require periodic maintenance too. Leaching pits are simple in their operation and perform the function of dispersing the incoming wastewater into the surrounding subsurface. Over time, the remnant solids occupy the full volume of the pit requiring its desludging. On the other hand, the accumulation of solids in the septic tank begins to constrain its settling performance long before they fully fill it up to the point of non-usability. As the volume of sludge builds up in the tank, the hydraulic retention time of the incoming wastewater reduces, in turn reducing the BOD removal rate and, resultingly, the quality of the exiting tank effluent. The Indian Code of Practice recommends desludging the tank when the scum layer at the top of the septic tank and the sludge layer together exceed half of the effective septic tank depth. Guidance on appropriate desludging rates from other countries like Australia and Ireland use the same yardstick, with limiting values for the volume of sludge ranging from 30% to 50% of the total working volume of the system.

Applying the principle to calculate the desludging rate for the average urban Indian septic tank with five users leads to a safe frequency of 8–10 years (**Table 2**). This means, that in theory, a septic tank under these conditions would continue to impart the acceptable level of performance until 8–10 years of operation. Nonetheless, in the absence of sludge level sensors, subsoil dispersion systems that begin to clog as septic tank performance deteriorates, and a periodic inspection programme for septic tanks, households cannot be expected to know when the sludge has crossed the halfway mark. Accordingly, as per the survey, 65% of the households reported issues like the clogging of their toilet and backflow from the tank to the toilet as the triggers for seeking desludging services. This means that households tend to desludge the tank when the sludge has accumulated as high as the water line, way beyond the recommended

Recommended Desludging Frequency (in years)							
Number of Users	Size of Septic Tank (in litres)						
	1,000	3,000	5,000	7,000	9,000	10,000	13,000
2	2	6	10	14	18	20	25
5	1	2	4	5	7	8	10
8	<1	1	2	3	4	5	6

Table 2.
Estimated desludging frequencies (in years) for different sizes of septic tank and number of users.

level. Then it is not a surprise that with their large sizes, the septic tanks that have been desludged have been in operation for 21 years on average. Overall, only 13% of all tanks had been emptied even once in their lifetime (13 years on average).

3. Improving on-site systems to achieve Sustainable Development Goal 6

Due to their unchecked and unregulated proliferation, on-site systems have mutated on the ground in response to the needs of the households (**Figure 4**). In urban India, households maximise the size of their on-site system subject to constraints of capital and space to reduce the incidence of maintenance or desludging events. The behaviour evinces the household's conception of on-site systems not as an active decentralised wastewater management system, but instead as a passive faecal waste containment structure (possibly rooted in the desire to 'flush and forget', if they can afford to, like sewered households). Overall, the phenomenon is not endemic to India, and similar issues in the quality and common perception of on-site systems prevail in countries like Bangladesh, Indonesia, Vietnam, and others in the Global South [16].

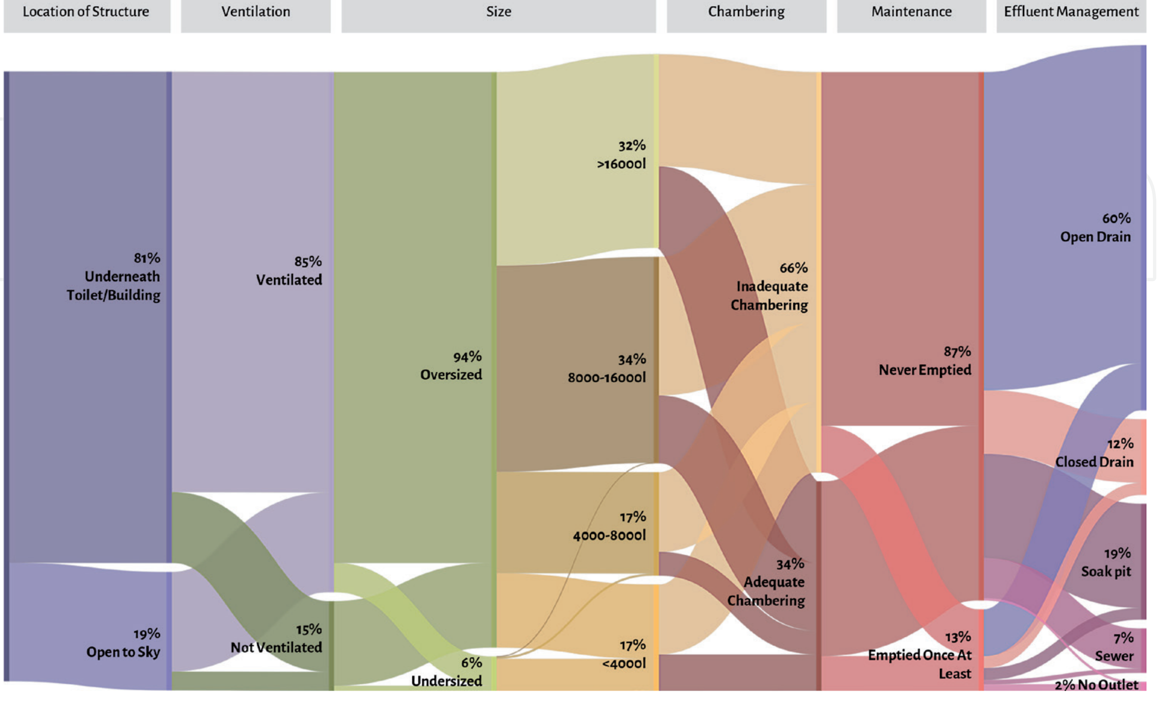

Figure 4.
Characteristics of on-site systems in urban India (reproduced from: Dasgupta S, Agarwal N, Mukherjee A. Unearthed - facts of on-site sanitation in urban India. Centre for Policy Research: New Delhi. https://doi.org/10.13140/RG.2.2.11717.06887).

As non-networked sanitation begins to find a place in mainstream planning and governance systems for citywide sanitation, it would be critical for city, state, and local governments to correct for the deficiencies in the household-level on-site systems for maximising the gains from sanitation investments. A three-point agenda, as discussed below, can guide the way for improving the entire ecosystem surrounding on-site systems towards achieving Sustainable Development Goal 6.

3.1 Shifting paradigm to on-site treatment without depending on soak pits and dispersion trenches

A septic tank, as a standalone unit, is not enough to manage wastewater on-site. A subsoil dispersion system together with the tank constitutes the conventional 'septic tank system' as a complete solution. Without a soak pit or dispersion trench, which release the tank effluent into the subsurface for further nature-based remediation, the effluent must either be treated more completely at the household level before being discharged into the environment or conveyed to an off-site treatment facility through closed channels for treatment. The applicability of each strategy changes based on context. For instance, soak pits and dispersion trenches are a low-cost and low-maintenance solution for effluent management in rural and low-density peri-urban areas. In areas with high density, conveyance and off-site treatment of tank effluent could work if retrofitting and interception of existing drainage channels is possible, or if the costs of creating such a system (like a small bore sewer system) anew are still lower than that of developing a full-sized sewerage system. Alternatively, higher in-situ treatment of the wastewater could help achieve a high level of sanitation without requiring significant investments in city-level infrastructure.

Each of the three strategies demands significant systemic changes to the broader ecosystem within which to implement them. For instance, both the construction of soak pits alongside existing septic tanks and the upgradation of septic tanks to newer, more advanced on-site systems require the willing participation of the household. The feasibility of the latter is additionally contingent on the availability of a flourishing prefabrication industry for on-site systems. Similarly, conveyance and treatment systems require sustained funding to build and operate.

Despite their conventionality, subsoil dispersion systems are unsuited to urban areas. Hydrogeological conditions form only one set of factors influencing the suitability of subsoil dispersion systems. Their spatial density also acts as a critical and limiting factor - with the recommended threshold of spatial density varying in the literature from as low as 16 to 495 units per square kilometres. In India, most cities lie at the higher end of the range and are denser still at the neighbourhood level, rendering the promotion of subsoil dispersion systems an unsuitable option [9]. Therefore, it is imperative that governments move on from viewing subsoil dispersion systems as a simple and appropriate fix to other strategies (**Figure 5**).

3.1.1 Learning from Japan

Up until the Second World War, Japan was primarily an agrarian society and relied on pit toilets, the faecal waste and sludge from which would be evacuated and used as a soil conditioner in farming. The government pursued the development of sewerage systems in the 1970s as the country started urbanising and densifying. With a rising level of affluence, even households in unsewered areas began transitioning to pour-flush toilets and created a need for a system that could serve as a complete on-site treatment system in the absence of a sewer connection.

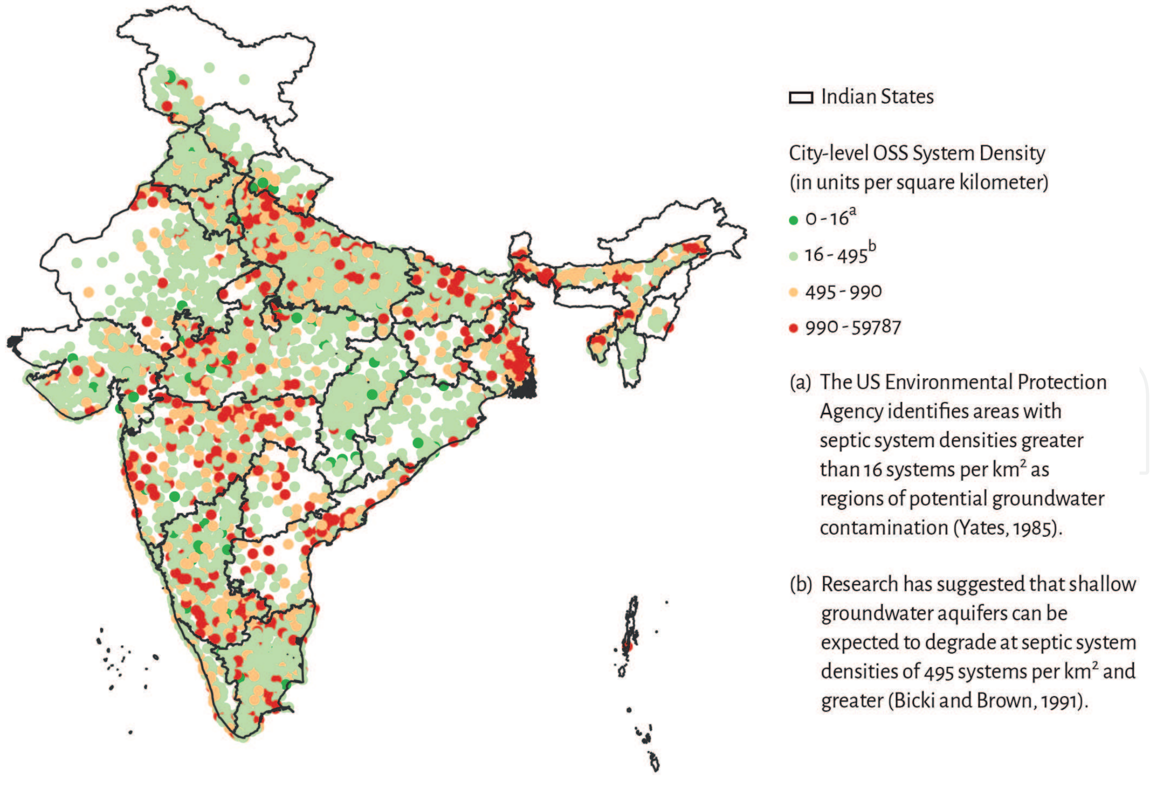

Figure 5.
Density of septic tanks at the city-level in India (reproduced from: Dasgupta S, Agarwal N, Mukherjee A. Moving up the on-site sanitation ladder in urban India through better systems and standards. J. Environ. Manage. 111656. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.111656).

The Tandoku-shori Johkasou (translated as blackwater-only on-site treatment system) gained popularity among households during this period and witnessed proliferation alongside the sewerage system, albeit without governmental regulation. However, within a couple of decades, the persisting issues of water pollution, ascribed to dysfunctional Johkasou systems, emerged at the forefront. To plug the gaps in sanitation and environmental management, the government enacted the Johkasou Law, or the Packaged Aerated Wastewater Treatment Plant (PAWTP) Law, in 1983. The Law enabled the standardisation of the Johkasou for complete treatment of blackwater, its manufacturing, installation and maintenance. The national and local governments created a subsidy programme to enable the rapid diffusion of the improved Johkasou among non-sewered households. In 2000, recognising that treating only blackwater was not enough for environmental protection, the government further amended the PAWTP Law to phase out Tandoku-shori Johkasou in favour of the Gappei-shori Johkasou that treats both black and greywater in the same system [16, 17]. As per the latest data from JMP (2017), Johkasou and older on-site systems continue to serve 23% of the country's total population.

3.2 Encouraging adoption of prefabricated on-site systems to improve performance and standardisation

The speed of diffusion of improved on-site systems and technology, in general, is dependent on a mix of social, economic, and technical factors. Existing research has described the adoption of innovation as 'primarily the outcome of a learning or communications process' [18]. In a densely-populated and urbanising country like India with low levels of baseline technical expertise on safe on-site systems among masons and weak local governance capacities for their regulation, achieving diffusion of new systems at speed and scale would follow a tedious and long trajectory with in-situ construction.

A small set of, and often regional, prefabrication industries for on-site systems already exists in the country. The national and state governments should collaborate with the industrial players to create a portfolio of prefabricated on-site systems that perform advanced (secondary/tertiary) treatment of incoming blackwater and greywater. As part of such a strategy, the government should consider subsidising either the industry or the households directly to bring down the cost of prefabricated on-site systems, the latter like in the case of Japan, and make them competitive with the dominant practice of in-situ construction. Alternatively, or in complementing the subsidisation, the government could adopt a command-and-control approach where it mandates the adoption of certified prefabricated on-site systems among certain categories of users, such as commercial centres, institutional buildings, apartments, and others.

3.2.1 Learning from Malaysia

Malaysia has been one of the flag-bearers of non-networked sanitation and FSM among developing countries, with 20% of its population dependent on on-site sanitation as per JMP (2017). The country has experimented with different frameworks to streamline the co-existence of non-networked sanitation and sewerage systems, as well as, created specific models for the governance of the former, including scheduled desludging. Until the 1990s, septic tanks constructed in-situ were the predominant on-site systems in the country. As a small prefabricated industry for on-site systems began to flourish from then onwards, the Malaysian regulators took cognisance of the opportunity to effect a fundamental shift in the sanitation sector and issued the Malaysian Standard 2441–1 and 2441–2 for the quality-control of the prefabricated systems.

In its first part, the standard notified the design of an improved or enhanced septic tank combining a settling unit with an anaerobic filter for up to 30 population equivalent (PE). The second part covers those systems that perform higher treatment still through aeration and are appropriate for applications with 31 to 149 PE. The distinction between the two types – aeration-based for higher treatment and non-aeration-based for moderate treatment – realistically accounts for the need for incremental improvement. Within a couple of decades, in-situ construction of on-site systems is on its way out, with the prefabricated system being cost-competitive and more convenient for households.

3.3 Creating robust city-level planning and regulatory ecosystems for on-site systems

Rapid urbanisation and laggard service delivery systems have created new landscapes for the implementation of non-networked sanitation. Innovation in system design helps meets public health and environmental needs in these evolving contexts. However, the adoption of innovation and continuous process improvements are not possible without fundamental shifts in the encompassing ecosystem for planning and regulating urban infrastructure. Strong city-level planning systems are imperative to ensuring that households pick the correct option in on-site systems and construct or install it as per the prescribed guidelines. Secondly, a robust regulatory could help foster regular engagement with on-site systems and enable better performance through (a) monitoring of its overall compliance and quality and (b) identifying the need for desludging for improving operational performance. For example, in the case of urban India, the latter could look like local governments contracting desludging service providers to undertake scheduled inspections of on-site systems in addition to their primary responsibility.

3.3.1 Learning from Ireland

Ireland has one of the significant dependence on non-networked sanitation among countries of the Global North. As per JMP (2017), 32% of Ireland's total population depends on on-site systems – with the proportion being more than twice as high at 77% in rural areas. Since low-density rural areas are the major contributors to the dependence, the septic tank system continues to be a viable and the dominant type of system in use. Unlike India, where the Code of Practice recommends against treating 'wastes containing excessive detergents, grease, and disinfectants' in the septic tank, the Irish Environmental Protection Agency (EPA) clearly states that 'greywater in all circumstances be directed to the wastewater treatment system'.

The recently updated 2021 Code of Practice (CoP) for Domestic Waste Water Treatment Systems provides detailed guidance on on-site systems serving PE of 10 or less. The CoP behooves households to ensure that their on-site system complies with EN 12566, the standard for prefabricated assembled/packaged on-site systems, including septic tanks. The CoP requires households to select from the available on-site systems in consultation with the local authority following a site characterisation of their lot. It also discusses the appropriate desludging rates for septic tanks based on the different number of users and sizing. What is unique to Ireland is not its guidance and regulatory framework for on-site sanitation but its data-led inspection plan for monitoring and continuously improving the state of existing on-site systems.

Following the European Union Court of Justice ruling against Ireland under the 1975 EU Waste Framework Directive (Case C-188/08) in 2009, the country promulgated the Water Services (Amendment) Act 2012, which requires the EPA to prepare a national plan for inspection of at least 1,000 on-site systems annually [19]. The Act also requires households to maintain records of desludging. Since then, the EPA has carried out inspections in 2013 and 2015, with the third inspection plan for 2018–2021 underway. The latest inspection report from 2019 found that 51% of the inspected systems had failed, and 26% were a risk to human health or the environment. Under its new grant scheme, these failing systems are eligible for a grant worth €5,000 for improvements. The report noted that 73% of the systems that failed in previous inspections had been fixed.

4. Conclusion

Non-networked sanitation is a viable and necessary alternative to sewerage systems for public health and environmental management in the Global South. However, an erstwhile exclusive focus on developing sewerage infrastructure and viewing non-networked sanitation as a stopgap arrangement has led to poor institutional engagement with the state of the latter. On-site systems have proliferated under a laissez-faire regime, with households determining conventional design practices as a function of cost and convenience. These deviations from the scientific design have come at the expense of increased epidemiological risks and water pollution. In the run-up to the end of the SDG era, the agenda for citywide sanitation cannot exclude improving the quality of on-site systems and their performance. High-settlement densities necessitate a shift to advanced packaged-type systems for urban and peri-urban areas coupled with prefabrication to drive the change at scale and speed. Moreover, since operational performance is a function of both the design of the system and its maintenance, a regulatory programme and strengthening local governance capacities to deliver it are critical to long-term success.

Acknowledgements

The present work was supported by the Bill and Melinda Gates Foundation (BMGF), India (under the grant number OPP1136373).

Conflict of interest

The authors declare no conflict of interest.

Author details

Shubhagato Dasgupta* and Neha Agarwal
Scaling City Institutions for India, Centre for Policy Research, New Delhi, India

*Address all correspondence to: shubhagato@cprindia.org

References

[1] Schellenberg T, Subramanian V, Ganeshan G, Tompkins D, Pradeep R. Wastewater Discharge Standards in the Evolving Context of Urban Sustainability–The Case of India. Front Environ Sci [Internet]. 2020 Apr 17 [cited 2020 Apr 30];8:30. Available from: https://www.frontiersin.org/article/10.3389/fenvs.2020.00030/full

[2] World Health Organization (WHO). Guidelines on sanitation and health. 2019;

[3] Schrecongost A, Pedi D, Rosenboom JW, Shrestha R, Ban R. Citywide Inclusive Sanitation: A Public Service Approach for Reaching the Urban Sanitation SDGs. Front Environ Sci [Internet]. 2020 Feb 28 [cited 2020 Apr 30];8:19. Available from: https://www.frontiersin.org/article/10.3389/fenvs.2020.00019/full

[4] Supeck Septic Services L. The History of the Septic System – Supeck Septic Services [Internet]. [cited 2021 Apr 9]. Available from: https://supeckseptic.com/blog/the-history-of-the-septic-system/

[5] Schertenleib R, Lüthi C, Mintje AP, Depinder B, Abishek K, Narayan S, et al. A Sanitation Journey – Principles, Approaches & Tools for Urban Sanitation [Internet]. 2021 [cited 2021 Apr 9]. Available from: www.susana.org

[6] Dasgupta S, Agarwal N, Mukherjee A. Unearthed - Facts of On-Site Sanitation in Urban India [Internet]. New Delhi; 2019 [cited 2020 Feb 17]. Available from: https://doi.org/10.13140/RG.2.2.11717.06887. 2019.

[7] WaterAid. Quality and sustainability of toilets - A rapid assessment of technologies under Swachh Bharat Mission-Gramin [Internet]. 2017 [cited 2021 Apr 9]. Available from: https://www.wateraidindia.in/sites/g/files/jkxoof336/files/quality-and-sustainability-of-toilets.pdf

[8] Singh A. Building Regulations for Faecal Sludge Management : Review of Building Regulations. New Delhi; 2018.

[9] Dasgupta S, Agarwal N, Mukherjee A. Moving up the On-Site Sanitation ladder in urban India through better systems and standards. J Environ Manage [Internet]. 2020;111656. Available from: http://www.sciencedirect.com/science/article/pii/S0301479720315814

[10] Johnson S. The ghost map : the story of London's most terrifying epidemic--and how it changed science, cities, and the modern world [Internet]. Riverhead Books; 2006 [cited 2021 Apr 9]. 299 p. Available from: https://books.google.co.in/books/about/The_Ghost_Map.html?id=cWtglGzhPPEC&redir_esc=y

[11] Bancalari A, Martinez S. Exposure to sewage from on-site sanitation and child health: A spatial analysis of linkages and externalities in peri-urban Bolivia. J Water Sanit Hyg Dev. 2018;8(1):90-99.

[12] Manish, Singh T. Manual cleaning of sewers and septic tanks | Centre for Policy Research [Internet]. New Delhi; 2017 [cited 2021 Apr 9]. Available from: https://www.cprindia.org/research/reports/manual-cleaning-sewers-and-septic-tanks

[13] Gupta A, Coffey D, Spears D. Purity, pollution, and untouchability: challenges affecting the adoption, use, and sustainability of sanitation programmes in rural India. [cited 2021 Apr 9]; Available from: http://www.developmentbookshelf.com/doi/pdf/10.3362/9781780449272.017

[14] Mohanty R, Dwivedi A. Culture and Sanitation in Small Towns - An

Ethnographic Study of Angul and Dhenkanal in Odisha. Econ Polit Wkly [Internet]. 2015 Jun 5 [cited 2021 Apr 9];54(41):7-8. Available from: https://www.epw.in/journal/2019/41/special-articles/culture-and-sanitation-small-towns.html

[15] D'Amato VA. Factors Affecting the Performance of Primary Treatment in Onsite Systems | IWA Publishing [Internet]. IWA Publishing; 2008 [cited 2020 May 1]. 112 p. Available from: https://www.iwapublishing.com/books/9781843397816/factors-affecting-performance-primary-treatment-onsite-systems

[16] Hashimoto K. Institutional Mechanisms for Sustainable Sanitation: Lessons from Japan for Other Asian Countries [Internet]. 2019 Sep [cited 2020 May 5]. Available from: https://www.adb.org/publications/institutional-mechanisms-sustainable-sanitation-lessons-japan-other-asian-countries

[17] Gaulke LS. On-site wastewater treatment and reuses in Japan. In: Proceedings of the Institution of Civil Engineers [Internet]. Water Management; 2006 [cited 2021 Apr 10]. p. 103-9. Available from: http://courses.washington.edu/onsite/ICEPaperGaulkeJohkasou.pdf

[18] Brown LA. Diffusion: Geographical Aspects. Int Encycl Soc Behav Sci [Internet]. 2015 Jan 1 [cited 2021 Apr 10];406-10. Available from: https://www.sciencedirect.com/science/article/pii/B9780080970868720113

[19] Withers PJA, May L, Jarvie HP, Jordan P, Doody D, Foy RH, et al. Nutrient emissions to water from septic tank systems in rural catchments: Uncertainties and implications for policy. Environ Sci Policy [Internet]. 2012 Dec 1 [cited 2020 May 6];24:71-82. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1462901112001293