Small-Scale Sanitation in India: Research Results and Policy Recommendations

This policy brief presents the main results of the first systematic assessment of small-scale sanitation (SSS) in India. Extensive field data was collected in eight States of India in 2016 and 2017. This brief highlights the research findings and provides recommendations for strengthening the functionality and sustainability of India's urban wastewater sector.

There has been an exponential growth in the number of small-scale sewage treatment plants (SSTPs) serving from 10 to 1'000 households in South Asia's rapidly expanding urban areas. An estimated 20'000 such systems are in operation in India today, providing an alternative to conventional, large-scale centralised systems. Can these systems live up to their promise of providing a flexible, modular and cost-effective alternative to large-scale networked solutions? What is the technical, financial and environmental performance of existing SSTPs, and what determines the success or failure of such systems? These are some of the questions the 4S research consortium has sought to answer. This research aims to strengthen the functionality and adaptability of India's wastewater and sewerage infrastructure in the coming decades.

An overview of the Indian small-scale sanitation sector

Small-scale sanitation has been implemented in India for more than 30 years with NGOs and research institutes spearheading their implementation. More recently, there were major policy revisions by the Ministry of Environment and Forests (MoEF), which introduced the Environmental Impact Assessment (EIA) in 2004 and an amendment in 2006, mandating that buildings with large built up areas (above 20,000 m2) must manage their wastewater on site. This has triggered the uptake of SSTPs across the country. Although there is no formal national small-scale sanitation policy framework, individual states such as Karnataka, Goa, Kerala, Tamil

Nadu, and cities such as Bangalore, Chennai, Hyderabad, Pune, have developed their own individual SSS policies.

A wide variety of SSS technologies are available in the market, from Activated Sludge Processes (ASP) to Membrane Bio-Reactors (MBR). Yet, there is no comprehensive database that lists the numbers and kind of technologies employed in SSTPs. Technology choices are largely vendor-driven and influenced by scale and context (low-income/high-income residential, commercial, and institutional). Given the huge similarities between the technological processes among the diverse options, these are largely grouped into seven technology families.

Due to increasing demand for SSTPs, which is predominantly catered to by the private sector, hundreds of private companies were found to operate across the country. They offer a range of services that include consultancy, design, turnkey solutions (including design, engineering, procurement, construction and commissioning), and operation and maintenance, while a few offer all the above. In this study, 308 such companies were identified.

As part of the 4S study, a total of 9,497 SSTPs were catalogued from various sources (project partners, Government websites, private players, literature and right to information requests). Of these, 318 SSTPs across India (Figure-1) were visited in person for qualitative performance assessments, and detailed water quality studies were undertaken for 35 SSTPs. These formed the basis for the detailed studies on technical aspects of the project.

Table 1: **Classification of Key Small-Scale Sanitation Technology families**

Technology Family	Examples
Suspended Growth Processes	Conventional Activated Sludge Process (ASP), Extended Aeration (EA), Oxidation Ditch, Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR)
Attached Growth Processes	Moving Bed Biofilm Reactor (MBBR), Submerged Aerated Fixed Film Reactor (SAFF), Rotating Biological Contactor (RBC)
Anaerobic Baffled Reactor (ABR) Based Systems	DEWATS, DTS
Constructed Wetlands and Soil Filtration Systems	Horizontal-Flow, Vertical-Flow and Hybrid Constructed Wetlands, CAMUS-SBT, SIBF, Phytorid, SPISF
Other Systems	CAACO/FICCO, EADOx, Pond Systems, DRDO Biodigester

Main results of the evaluation

In the following chapter, the main findings of the two-year field research are presented. This is structured in four sections: (i) Sustainability and Technical Performance, (ii) Policies and Institutional Factors; (iii) Monitoring Systems and (iv) Financial Evaluation.

Sustainability and Technical Performance

Technical performance

Performance analysis (Figure 2) shows that for biochemical and phydical effluent quality levels (BOD, COD, TSS), any technology if combined with the right post-treatment units and operated correctly has the potential to achieve quite stringent standards. The rest of the parameters subject to the Central Pollution Control Board's (CPCB) effluent standards, however, are systematically not met. The nutrient levels are not reached, and it appears that nutrient removal is more a side-effect of the biochemical treatment than a goal by itself in the assessed SSS systems especially since most systems lack treatment units for nutriant removal (e.g. nitrification-denitrification).

Microbial quality of effluent is consistently not met in almost all systems analysed. Systems with disinfection steps (e.g. chlorination in most cases) do not ensure a better microbial removal rate and effluent quality than systems that do not disinfect. This indicates both too high organic concentrations before disinfection, as well as a wrong operation of the installed disinfection infrastructure.

Solids management is another major issue observed. A majority of the SSS systems studied do not consistently treat and safely dispose of the sludge they produce. With a lack of alternatives, sludge is often disposed of in nearby drains, water bodies or land, nutralising the benefits obtained by treating the wastewater.

The analysis of the water reuse practices highlights the good impact of the water reuse policies established over the last decade in the wake of increasing water stress. Reclaimed water from SSS systems is commonly used for toilet flushing and gardening. This practice can reduce the freshwater consumption of a building or campus by 30% or more. Unfortunately, a significant amount (typically in the range of 25–70%) of the treated wastewater cannot be reused due to lack of local reuse opportunities.

Sustainability of systems

In the project, the factors that can influence a system's successful long-term performance were analysed. Such success factors can be found in five different performance enabling domains: Planning, Design and Implementation; Operation and Maintenance; Management and Monitoring; Socio-Cultural Aspects; and Finances (Figure 3). Among them the following areas of concern are highlighted here:

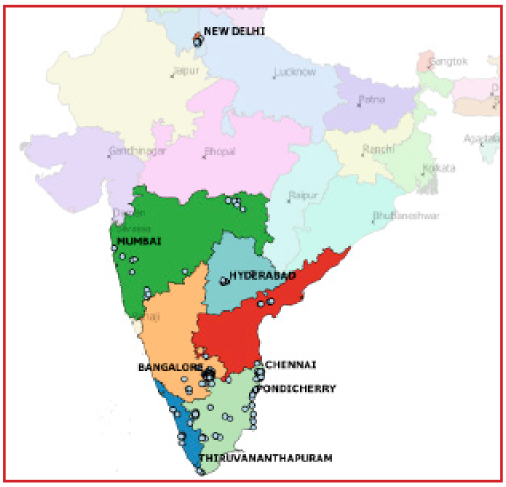

Fig. 1: **Sites visited in eight States in India**

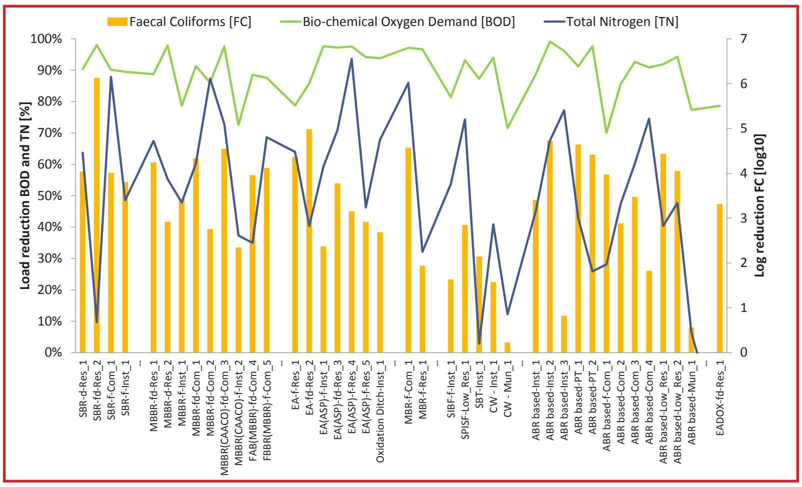

Fig. 2: **Averaged removal performance for key water quality parameters of the sampled SSTPs, grouped by technology families.**

i. System start-up and hand-over: The period in which ownership and/or responsibility are transferred from the designer/builder to the management entity was found to be crucial. Proper knowledge transfer and support from designers and implementers during this process is important to lay the foundation of long lasting and robust SSS systems.

ii. Skills and knowledge of operation & maintenance (O&M) personnel and management entities: Operators and managers are often not sufficiently informed about the functioning of SSS systems and the requirements for good performance. Trouble shooting skills are, therefore, generally weak.

iii. Supervision of O&M activities: Operators are often not clearly instructed and supervised. This can result in unclear or neglected responsibility and lack of information exchange.

iv. Documentation of O&M activities and financial flows: The absence of systematic documentation and archiving of information leads to the loss of knowledge and lack of understanding of the systems' performance and history. Such data is crucial for decision-making.

v. Anticipation of maintenance works: Clear responsibility for organising spare parts, as well as for planning and budgeting scheduled maintenance services, is lacking. As a consequence, there are a substantial risks of lasting system failures.

Policies and Institutional Factors

At national level, there is a lack of a clear policy framework for small scale sanitation. The role and scope of SSS is not explicitly mentioned in the State Sanitation Strategies and only rarely in City Sanitation Plans.

Overlapping jurisdictions of the concerned agencies hamper the planning and implementation process. Currently, the majority of the small-scale wastewater regulations are reliant on real-estate development authorisations through the 'consent for establishment'. Coordination between the planning, implementing and monitoring agencies is necessary for better overall functioning of urban wastewater management.

Furthermore, the capacity of these agencies has not kept up with rapid expansion in the sector in recent years. There is a need for more human resources in this area.

Presently, there is a mismatch between supply and demand regarding water for reuse in urban areas. Therefore, much of the treated wastewater cannot be used onsite (i.e. "zero discharge policies" are difficult to enforce in densely urbanised areas) and the link between supply and demand is not formalised. Better policies need to be introduced at municipal level to encourage water reuse.

Monitoring Systems

The Pollution Control Boards (PCBs) have a clear regulatory role and must stay ahead of the curve to ensure public health and environmental protection objectives in India's rapidly evolving urban sanitation sector. However, the on-going performance of SSTPs is largely unknown at national, state and municipal levels and there is a lack of standardised performance monitoring.

Wastewater samples of STPs are currently tested in accredited laboratories. However, samples are often taken by the system owners themselves and sent to the laboratory, which sends the results back to the system owner. Only the effluent quality delivered by the SSS systems is assessed and these assessments rely on potentially unrepresentative and costly grab samples. The 4S project shows that a more holistic analysis along the five performance-enabling domains (Figure 3) can reveal a more complete picture of a system's status and necessary improvement measures. Current monitoring approaches could be complemented by integrating the data from key 'soft' parameters, i.e. O&M and management activities, as well as observation of the functional status of the system. A more holistic monitoring approach has the potential to identify the causes of potential problems, while minimising sampling frequencies (see recommendations further below).

Financial Issues

The lifecycle costs (capital, operational plus capital maintenance costs) were analysed for different commonly used systems in India. Figure 4 shows these costs over a 20-year period, from small units with 40 KLD treatment capacity (left) to larger units with 700 KLD treatment capacity (right). This shows that lifecycle costs vary greatly depending on technology, system size and level of operation and maintenance. Here, Constructed Wetlands, Soil Filtration and Anaerobic Baffled Reactor Based Systems have the lowest costs due to low operational expenditures over a system's lifetime.

The analysis identified an unsustainable approach to financing SSS. Real estate developers commission systems and seek to minimise their capital costs, which often entails high operating costs on the part of future owners. A more realistic approach to financial sustainability would need to consider entire life cycle costs.

There is a lack of accountability from consultants, technology suppliers and system integrators of SSS, resulting in low quality installations and failures in the long-term operation of newly built systems.

Main recommendations

Sustainability and Technical Performance

Improving the sustainability of SSS systems in India

A good organic effluent quality can be achieved by combining measures to ensure the proper operation and maintenance of the systems with an efficient monitoring framework. However, it is not realistic to expect compliance with stringent nutrient standards from most of the existing systems. If current standards for nitrogen parameters are to be fulfilled, treatment systems must account for this in their process design. While this could be implemented for newly planned systems in the higher capacity size range, it may be necessary to lower the bar for existing smaller systems. Concerning microbial effluent quality, measures ensuring the correct design and operation of disinfection units, as well as reuse-specific standards, are required to ensure a safe reuse of the treated wastewater.

The issue of solids management should be addressed strategically by either having on-site sludge treatment facilities or by providing off-site centralised treatment systems that can handle the produced sludge from the surrounding SSS systems. Any newly planned infrastructure for the treatment of faecal sludge, sewage sludge or septage should include the capacity for receiving the produced sludge from existing or future SSTPs in the catchment area.

A clear, standardised procedure for the handover of plants to end-users and long-term owners is required. A systematic transfer of knowledge, design details, user-friendly and comprehensive operational manuals and other technology specific requirements should take place to ensure proper operation after designers and builders are no longer involved. Also, mandatory training and licencing of operators should be established and complemented with technology, design and context-specific O&M requirements. Training for the personnel of management entities should also be promoted and incentivised, namely on aspects including life-cycle cost planning, O&M requirements, as well as performance monitoring and optimisation.

Mandatory documentation of financial details, as well as of O&M activities, would allow traceability of the systems' operation and upkeep. Analysis of such information should also become part of the monitoring procedures. In the long term, online logbooks should be established for all systems.

Monitoring Systems

Creation of a Centralised Online Data Platform

Currently, different governmental agencies collect information on small-scale treatment plants without much coordination. This results not only in duplication of efforts, but also in data gaps and overlaps. As a first step, a centralised online data platform should be created, ideally under the auspices of both the State Pollution Control Boards (PCBs) and the responsible Urban Local Bodies (ULBs). The Central Pollution Control Board must then collate the data and ensure the upload of records on locations, system specifications and system performance by different agencies in a standardised format. There needs to be agreement on the merging of the various existing databases to create a national (or state-based) repository. It is essential that each SSTP can be tagged and that each receives a unique identification code. Geo-¬referencing of all units is necessary to ensure follow-up and to eventually introduce Internet-based monitoring tools.

There needs to be a clear allocation of the roles and responsibilities for data collection at the various levels of Government (national, state and ULB). For this central repository, it is proposed that the data be collected city-wise, and analysed at state and national levels. Different management options for running this online platform could be evaluated, e.g. having a mandated private company do the delegated database management (as practiced in Malaysia).

Compliance Monitoring

It is suggested that standardised sampling (standard procedures and parameters) for small-scale treatment plants should be conducted more frequently. The sampling could be carried out by the concerned government agencies or when they lack capacity, it could be delegated to private monitoring companies as sub-contracts. Such a mechanism would be effective in widening coverage by the authorities and to increase the data collection abilities. Complementing hard monitoring (water quality testing) by soft monitoring, which would consist of observations of the treated wastewater, the general health of the plant, the functionality of the different components, and checking O&M and financial logbooks, have an enormous potential to reduce sampling needs and, therefore, present a good cost saving opportunity. However, in order to not be over-reliant on the inspector's observations and prevent any wrong-doing, such soft monitoring also must be standardised and must be complemented with visual evidence documentation. This prevents a loophole in the monitoring framework and contains the necessary checks and balances.

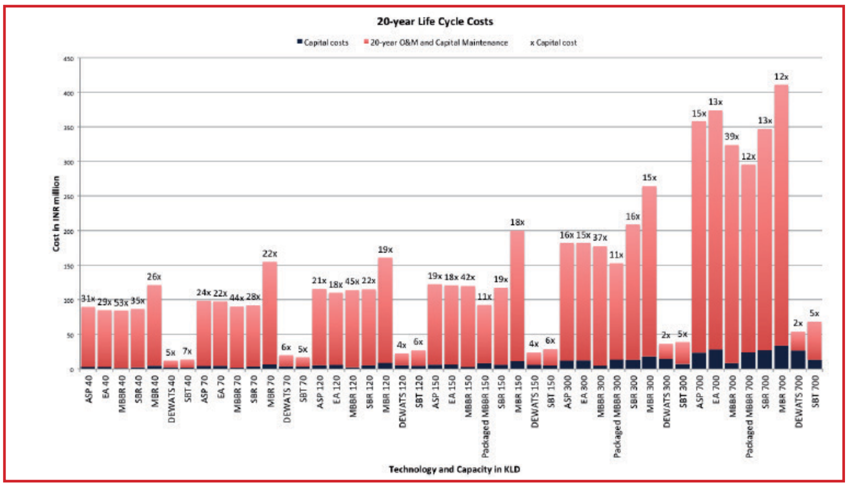

Fig. 4: **20-year life cycle costs for small units with 40 KLD treatment capacity to larger units with 700 KLD treatment capacity.**

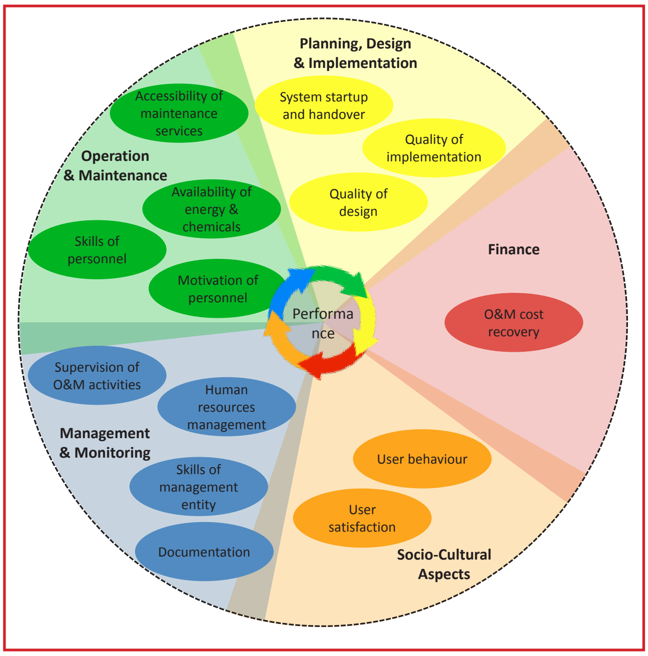

Fig. 3: **A total of 14 success factors was identified in five performance enabling domains.**

In the future, online monitoring devices could reduce the need for onsite sampling. The data collected could help inspectors to prioritise systems for inspection. Presently, these devices are expensive and there is a risk of misuse and manipulation of the instruments. However, the development of simpler and cheaper remote monitoring devices is in progress and should be followed-up. When wastewater samples are analysed, the results should go to the Pollution Control Board directly by being uploaded onto the online database using the identification code. This will allow a rapid follow-up in case of non-compliance, but also automatic checks if the results are questionable. In the long-term, improvement in remote monitoring devices and sensors will enable the monitoring of key parameters without requiring a visit to STPs.

Water Supply and Sewerage Boards or ULBs need to create a dedicated SSTP unit, consisting of trained professionals, as they are the government bodies closest to implementation and have the required technical expertise and human resources. In cities with staff shortages, delegating the monitoring responsibility to a private company could also be considered as a medium-term measure.

Policies and Institutional Factors

National Policy Framework

At national level, the MoHUA should spearhead the development of a clear policy framework for small scale sanitation. Technical specifications and approved design standards need to be developed, so that funds can be channelled from national level down to ULBs for SSTPs. Guidelines for the design of small scale sanitation systems need to be updated, considering the wide variety of technologies now on the market.

Improved Strategic Planning

The role and scope of SSS should be explicitly stated in the State Sanitation Strategies and every City Sanitation Plan. This will allow for the making of informed deci-

Box 1: Key messages

- MoHUA must spearhead the policy framework for small scale sanitation, including technical specifications, design guidelines and compliance monitoring.
- The creation of a centralised online data platform, ideally under the auspices of the Central Pollution Control Board (CPCB), would facilitate the supervision of system and urban water management planning.
- ULBs and water supply and sewerage boards should be able to access and update the database of SSTPs and be involved in their planning. This would avoid overlaps with the coverage of large-scale systems and allow a coordinated reuse of excess treated water and sludge management.
- Better enforcement mechanisms should be developed to improve compliance of service providers.
- A clear, standardised procedure for the handover of plants to long-term owners is required. A systematic transfer of knowledge is crucial.
- Systematic training and licencing of operating personnel is needed to ensure well-functioning STPs.
- Lifecycle costs are the key factor to consider when comparing the costs of different STPs, particularly operation & maintenance, and trained manpower and electricity costs.

sions about future investments for sanitation improvements, as well as the prudent use of resources to meet recognised priorities.

ULBs should produce and maintain sanitation maps indicating existing sewer networks, SSTPs and faecal sludge management infrastructure. This will promote the mapping of areas to be served by SSS and faecal sludge management. SSS policies need to be in line with the sewerage strategies of the cities, to define coverage areas and avoid overlap. Such zoning should be based on the optimal scale of sanitation systems, which is a function of availability of funds, lifecycle costs, management constraints and the wastewater reuse strategy.

Encouraging Water Reuse

Reuse policies need careful planning and must be based on a good understanding of the situation and the implications for the users. Reuse opportunities, availability of space for the treatment facility, feasibility of retrofitting dual plumbing systems in existing buildings and cost implications are crucial aspects to consider when drafting effective and realistic policies.

Currently, there is a mismatch between supply and demand regarding reuse of water in urban areas. Much of the treated wastewater cannot be used onsite (i.e. “zero discharge policies” are difficult to enforce in densely urbanised areas) and the link between supply and demand is not formalised. There is a potential market opportunity to develop a georeferenced ‘Uber-style’ app allowing companies/institutions needing treated wastewater to identify the suppliers. As the potential end-users (e.g. construction sites) need a certain quality of treated wastewater, this would also incentivise service providers to achieve the required level of treatment.

Financial Recommendations

Purchasing decisions should be made based on life-cycle costs, not just capital costs. The findings show that the O&M costs along with inflation has a cumulative impact on life-cycle costs which outstrip the initial capital costs many-fold. To improve O&M of SSS, special financial resources should be earmarked by developers to cover at least 10 years of O&M and capital maintenance costs. Depending on the value of the real estate, this would add 0.1–0.5% to the cost price of the real estate.

State Governments should provide incentives for building good-quality STPs and operating them well, e.g. a well-operated STP should benefit from subsidies through lower development charges or property taxes because they save substantial money and work for the Government. Tax incentives should encourage developers to invest in more robust and reliable premium systems. If the residents’ welfare association is operating the system very well for five years, it should get a rebate on property tax or water rates.

The accountability of consultant technology suppliers and system integrators needs to be improved by making them liable for operational failures. This should include penalties, such as blacklisting at state and national level, and stiff fines that are significantly higher than the O&M costs.

Box 2: About 4S (Small-Scale Sanitation Scaling-Up)

4S is a joint research initiative conducted by Eawag (the Swiss Federal Institute of Aquatic Science and Technology), the Indian Institute of Technology (IIT) Madras, BORDA, Germany, and the CDD Society in Bangalore. This draft policy brief was first presented to a national audience on 05 April 2018 at the Indian Habitat Centre in Delhi. Please provide your feedback and comments to lukas.ulrich@eawag.ch.
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