Status, Sustainability and Technical Performance Assessment of Small-Scale Decentralized Sanitation Systems in Nepal

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ABSTRACT

Small-scale sanitation (SSS) is a proven alternative to conventional centralized wastewater management. While at least 67 SSSs exist in Nepal, there is little information on their performance and long-term success. An extensive study was conducted to assess the status of SSSs in the country and to develop evidence-based recommendations for their improved management in the future. This paper analyses data on system configuration, implementation, management setup, operation and maintenance, technical performance, socio-cultural and financial aspects which were collected for 30 systems. Similarly detailed analysis of the technical performance of 5 systems based on 24-hour composite samples of influents and effluents for three consecutive seasons.

Altogether 22 systems were found to be fully or partially operational and 8 systems were non-operational. 46.7% of the system managers had received training on basic operation and maintenance (O&M); 75% of the systems have designated caretakers in community/municipal systems and 55.6% in institutional systems. 87% don’t have planning and regular budget allocation to operate the system. Regular desludging was practised in only 47.6% of the operational systems, and 36.3% of the systems have had to unclog the constructed wetland. In an aggregated performance, 36.4% of the systems were evaluated as sustainable, while 54.5% were at risk and 9.1% of systems were not sustainable. Average BOD and TSS removal efficiency was 86% and 92% respectively. The major shortcomings for non-sustaining performance were top-down approaches of initiation, lack of user participation in technology choice, misconception of systems as maintenance-free, ignorance of repair and renovation requirements. Thus, an increased involvement of users, an operating manual and plan, clear responsibilities of stakeholders, adequate effluent standards, regular monitoring, and sustainable financing mechanisms for O&M are essential for the long-term performance of SSS systems.

KEYWORDS
Management, Operation and Maintenance, Planning and Implementation, Small-Scale Sanitation System, Sustainability, Wastewater

INTRODUCTION

Wastewater management is a process that collects and conveys wastewater to designated treatment plants which remove pollutants to protect the environment and safely dispose or reuse water such that it reduces health hazard or adds value to productivity. However, in Kathmandu Valley, common management practice involves discharging of untreated sewage into aquatic environments without proper treatment, although some early initiatives were made.

Small-scale decentralized sanitation systems were seen as more appropriate because of their simplicity and cost-effectiveness as compared to traditional centralized systems in the context of Nepal (ENPHO 2008). Since the successful demonstration of the effectiveness at institutional and community levels, at least 67 systems have so far been constructed in many parts of the country. In 2010, ENPHO conducted the performance assessment of some SSS installation in Kathmandu Valley based on one-time grab sampling, a weak method to assess the long-term treatment performance. In this paper, the status, sustainability assessment and removal efficiency of SSSs with identified shortcomings and recommendations for sustainable management is presented.

METHODOLOGY

Selection of Systems

Altogether 30 systems were selected based on predefined hard and soft criteria. The systems are located in 10 districts from the hilly and Tarai areas of the eastern, central and western region. The hard criteria consist of mandatory conditions. Systems had to be operational for at least two years since installation and only established technologies with a potential for scaling up were considered. Selected installations have a treatment capacity of 10-1000 households (approx. 5-700 m3/day) and they exclude industrial treatment plants. The soft criteria include representation of different geographical and climatic contexts, ease of access and different contexts of applications. The selected 12 and 18 systems can be categorized as community/municipal and institutional systems respectively and provided with a code for all systems. Among these, 5 operating installations were selected for evaluation of organic and nutrient removal efficiency. The code for selected systems 4S-002-N and 4S-020-N was installed at municipal and community level. Other systems with code 4S-004-N, 4S-005-N and 4S-009-N were institutional systems operated in hotel, hospital and school respectively.

Data Collection

An in-depth survey was conducted with management entity representatives, operators/caretakers and users of the systems. The questionnaires included sections on the installation’s history, system configuration, O&M, management and financial setup, and perceptions towards the system. A qualitative technical inspection of the SSS systems was carried out using an observation checklist. While 24-hour composite sampling for influent and effluent was collected and laboratory analysis on physical, chemical and microbiological parameters was conducted for three consecutive seasons.

Data Analysis

The four sets of data collected from the questionnaire survey were arranged and triangulated. A descriptive statistical analysis was conducted to understand the current status of the systems. The data were used for a sustainability assessment of the performance of the operational systems. Five criteria including planning, design and implementation, management setup, financial, socio-cultural and operational status were assessed using various indicators. The responses or information in each indicator were rated and provided with the score as shown in Table 1. The criteria and weightages were fixed based on interaction with practitioners, experts engaged in design and promotion of the systems. In order to rate the sustainability of the systems studied, an aggregated score was calculated for each of the criteria. The rating was made as follows based on the achieved scores in relation to the highest possible score: sustainable (>75%), at risk (50-75%) and unsustainable (<50%).

Table 1 Sustainability Assessment of Performance Framework

Criteria	Indicator (Weightage)	(Rate-score)
Planning, Design and	Project Initiator (5)	User Demand (E-5), Local Government (VG-3.3), Donor (G-1.6)
	Technology Selection (5)	User Proposed and selected (E-5), Final informed choice among several options (VG-3.75), Approved the purposed solution (G-2.5), Not involved (B-0).
	Ownership of the system (5)	User (VG-5), other (G-3.3), Unidentified (B-0)
	Ownership of the Land (1)	Same as treatment plant (VG-1), other (G-0.6), Unidentified (B-0)
	Ownership of Sewer (1)	Same as treatment plant (VG-1), other (G-0.6), Unidentified (B-0)
	Site Risk to Natural Disaster (3)	No Risk at all (VG-3), Occasional Risk (G-2), Every Year (B-0)
Management Setup	Overall Management of treatment	Owner of the system (E-4), Private Company (VG-2.6), Local Government (G-1), None (B-0)
	Management of Sewer Network	Same as Treatment Plant (VG-1), other (G-0.3), None (B-0)
	Capacity of management body	Well trained (VG-2), Trained on Basic O&M (G-1.3), Not trained (B-0)
	Responsible for Daily O&M	Designated Caretaker (E-3), Member of Managerial Body (VG-2.4), Gardener/Watch Man (G-1.8), others (B-1.2), None (VB-0)
	Capacity and Skill of Caretaker/Operator	Well trained (VG-4), trained on plumbing (G-2.6), Untrained (B-1.3)
	Provision of Incentives to caretaker	Regular Salary and incentives (E-3), Regular Salary (VG-2.25), Paid on work basis hour (G-1.5), Voluntary (B-.7)
	Frequency of involvement of caretaker	Every Day (E-3), Twice a week (VG-2.2), Once a week (G-1.5), Only when problem exists (B-.7)
Socio-cultural	User Informed on System	yes (VG-2), yes but not followed (G-1.3), No (B-0)
	Absence of complaint	Yes (G-2), No, someone complains (B-1)
	System Fulfilling the objective	Totally fulfilling (VG-2), Partially Fulfilling (G-1.3), Not at all (B-0)
	Perception of Technology	Excellent-2, Very Good-1.6, Good-1.2, Bad-0.8, Very Bad-0
	Perception of quality of treated water	Excellent-2, Very Good-1.6, Good-1.2, Bad-0.8, Very Bad-1
Financial	Debt on construction	No (VG-1), yes regularly paid (G-0.3), yes and no source to pay (B-0)
	Source of revenue	Yes, (VG-4), Insufficient for operating (G-3), No source (B-0)
	Reliable source for repair/upgrade	Additional Invest from User (E-5), local government (VG-3.75), Donor (G-2.5), No source (B-0)
	Provision of O&M Fund	Yes (VG-10), Overall maintenance Fund (G-6.6), No (B-0)
Basic O&M Status	Absence of unauthorized connection	Yes (G-4.5), No (B-0)
	Absence of excessive solid wastes	Yes, no solid waste at all (VG-1.5), No, but removed regularly (G-1), No (B-0)
	Absence of accumulated grits	Yes, (VG_1.5), removed regularly (G-1), No (B-0)
	Absence of excess sludge accumulation	Yes (VG-3), No, Regularly desludged (G-2), No (B-0)
	Provision of Sludge Removal Unit	yes (VG-2.2), Private Emptier (G-1.5), No any mechanism (B-0)
	Absence of Excessive Scum	Within limit (VG-1.5), Excess but removed regularly (G-1), No (B-0)

	Even distribution of wastewater in CW	Yes, (VG-3), distributed on half of the inlet section (G-2), No (B-0)
	Filter media is not clogged	Not clogged (Vg-2.2), Clogged at inlet zone (G-1.5), No (B-0)
	Regulated Water level in bed	Yes (G-1.5), No (B-0)
	General Appearance	Clean (G-1.5), Dirty (B-0)
	Smell emanation	normal/no smell (G-1.5), Strong smell (B-0)
	Absence of relevant corrosion of structure	Yes (G-1.5), No (B-0)
	Position and conditions of different Fixtures	As per Designed (VG-3), Replaced but not fully appropriate (G-2), Damaged and not replaced (B-0)
	Not accessible to unauthorized person	Yes (G-1.5), No (B-0)

The parameters such as COD, BOD, total phosphorous (TP), total nitrogen (TN), ammonia-nitrogen (NH_4-N) and faecal coliform from composite samples were analyzed to assess removal efficiency.

RESULTS AND DISCUSSION

STATUS OF SMALL-SCALE SANITATION SYSTEMS

Status of Planning, Design and Implementation

The primary objectives for installation of the systems were to protect the environment, particularly water resources and disease prevention, water reclamation and energy generation. User's participation during the planning phase is essential for a successful implementation and operation of the community/municipal sanitation systems. Active participation of users was only observed in 6 (50%) of community/municipal systems. They were participated in community meetings and workshops to get information on proposed technology, its benefits and the probable contribution they should make.

Management Setup

The Social and Environmental Section of the municipality, Community-Based Organizations (CBO) and Technical and Maintenance Units or specific management entities have the overall authority to manage the community/municipal and institutional systems respectively. Only in 14 (46.7%) systems, the management entity was trained on wastewater management. Designated caretakers/operators were appointed in 10 (75%) of the community/municipal systems for daily O&M of the systems. At institutional systems, skilled technical staff from either a technical and maintenance unit or similar unit were responsible for daily O&M in 10 (55.6%) systems and general staff such as watchmen, gardeners and helpers were mobilized as per requirements in other remaining systems.

Caretakers from 5 (41.7%) community/municipal systems were capable of executing daily O&M activities without any guidance and they were capable to discover, solve and prevent problems. Contradictorily, caretakers from only 3 (25%) systems had received basic training in daily operation and maintenance. In institutional level systems, caretakers mobilized from a technical and maintenance unit or similar were capable of discovering, resolving and preventing the problems without external guidance and were trained on basic O&M of the systems.

Financial Status

Planning and allocating regular budget for regular repair and maintenance was not practised in 26 (87%) systems. A major source of revenue was regular service charges collected from users in 7 (58%) community/municipal systems. In most community-level systems, a flat service charge per household connection ranged from minimum Rs. 200 per year to a maximum Rs. 600 per year were collected. Collection of service charges was not easy despite nominal amounts. Similarly, either area covered by a building or economic status of households were used for defining a service charge in other community/municipal systems which ranged from a minimum amount of Rs. 90 to maximum Rs. 250 per month.

Salary of caretakers, electricity charge for operating pumps, the cost involved in organizing meetings in the case of community/municipality level were a regular operational cost. The minimum Rs. 1500, average Rs. 7920 and maximum Rs. 20000 was observed regular operating cost in community/municipal system. In the institutional system the minimum, average and maximum amounts were Rs.300, Rs. 3925 and Rs. 10500 respectively. Similarly, the minimum irregular cost for desludging was Rs. 3000 and a maximum Rs. 36000 was observed in institutional and a community level system respectively. The maximum cost of Rs. 2.1 million was recorded for cleaning and replacing filter media of constructed wetland in a municipal level system.

Socio-cultural Aspects

Environmental protection, eco-friendliness and low operational cost were the most appreciated features in 20 (67%) systems. Also, the opportunity to generate energy and reclaim treated water from wastewater were appreciated by managers and users. While in 8 (26.7%) systems complaints on spreading of foul smell, the presence of flies and blockages and clogging were registered. A technology performance rating on a scale from 1 (worst) to 5 (best), showed that 2 (6.7%), 5 (16.7%), 16 (53.33%) and 7 (23.3%) systems scored 1, 3, 4 and 5 respectively.

Basic O&M Status

Accumulated sludge was within the limit of 10 (47.6%) operational systems while the remaining systems required urgent desludging. Also, there was no significant scum layer in only 6 (28.5%) systems. Constructed wetlands were inbuilt in 20 (91%) of the operating systems out of which only 3 (13.6%) systems have vertical flow type. There was no abnormal stagnant water on the bed in 8 (36.3%) systems. While stagnant water in the inlet zone and overflow of water from the surface were common in all the remaining systems. Also, only 7 systems have properly installed and functional swivel pipe. A clear effluent was produced in 10 (45.5%) installations, while slightly turbid in 8 (36.3%) units and very turbid in 2 (9%) units. No effluent flow was observed in 2 systems. The pH range of the effluent was in the normal range between 6.58 and 7.86.

SUSTAINABILITY ASSESSMENT OF PERFORMANCE IN OPERATIONAL SYSTEMS

In total, 16 (53.3%) systems were fully and 6 (16%) partially operational, out of which only 4 systems were built in community/municipal level. Correspondingly, 7 (26.6%) systems were not operational and 1 (3%) system completely abandoned. Table 2 shows the results of the sustainability assessment for the operational systems. The non-operational installations were assumed to be unsustainable due to their failure to provide a long-term service. The results show that planning, design and implementation of most systems were good as compared to other criteria. Socio-cultural and financial status of a majority of systems were at risk. The management setup and basic O&M was not sustainable for 5 systems. Thus, in terms of an overall sustainability performance, 12 systems were at risk, and only 8 out of 22 were considered sustainable.

Table 2 Result of Sustainability Assessment of Performance for the 22 Operational Systems

Criteria	Sustainable Systems	At Risk Systems	Not Sustainable Systems
Planning, Design & Implementation	16	5	1
Management Setup	9	8	5
Socio-Cultural	6	15	1
Financial	6	13	3
Daily O&M Status	8	9	5
Aggregate	8	12	2

Figure 1 shows aggregate scores for each systems. The aggregate score for 4S-002-N and 4S-020-N systems in all criteria were 65% and 66% indicating performance at risk. Similarly, an aggregate score of institutional systems for 4S-004-N, 4S-005-N and 4S-009-S were 76%, 78% and 79% indicating sustainable performance.

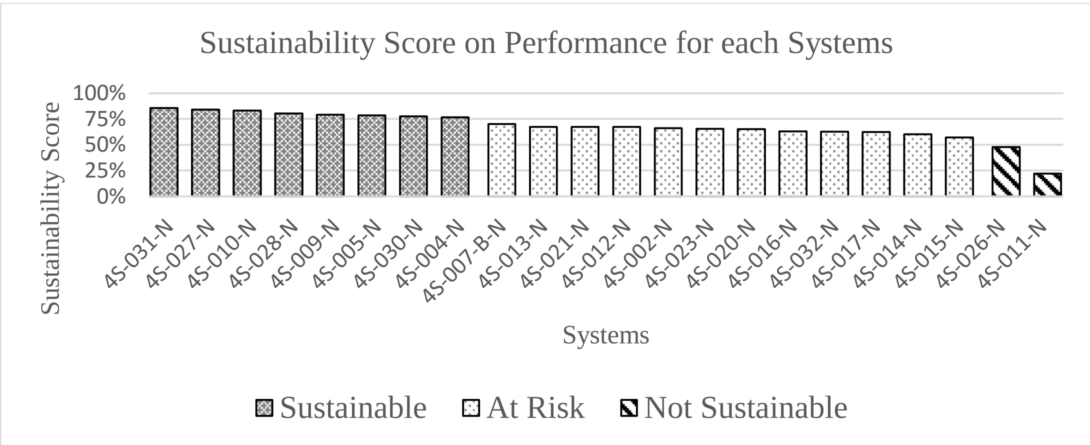

Figure 1 Score for Sustainability Assessment of Performance for Different Criteria

REMOVAL EFFICIENCY OF SSSs

The average removal efficiency for total suspended solids were achieved above 89% in all the systems. The BOD and COD removal efficiency was highest at the 4S-009-N at 96%. In 4S-002-N and 4S-020-N, installations at community/municipal level were comparatively lower than institutional installations as shown in Figure 2. The nutrient removal was only achieved in 4S-004-N and 4S-009-N while there was no significant nutrient removal in the other systems. Similarly, the maximum average removal efficiency for faecal coliform was achieved in 4S-005-N at 99% and minimum in 4S-002-N at 37%.

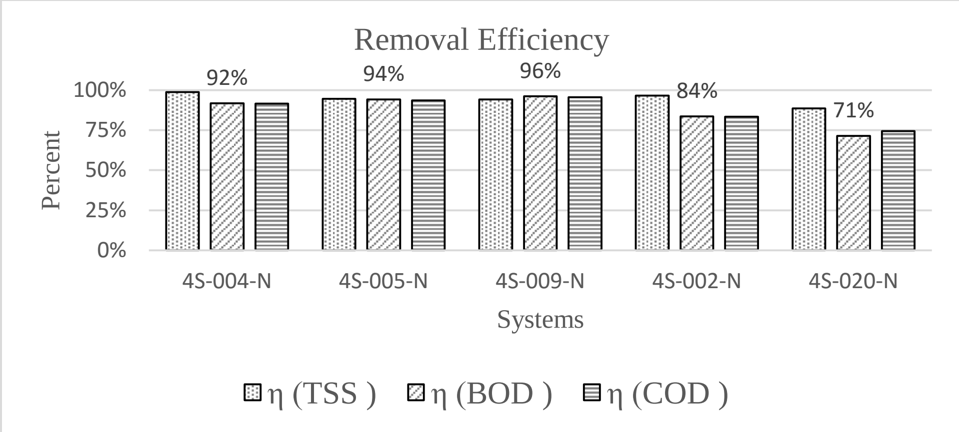

Figure 2 Removal Efficiency of BOD and COD during Three Consecutive Seasons

Thus it was observed that institutional systems with the higher score in sustainability assessment were more effective on removing organic matters and nutrients. However, the concentration of BOD in effluents exceeds tolerance limits for industrial effluents to be discharged into inland surface waters as per National Generic Standards of Nepal (2003). In case of COD, only samples from community system exceeded the standard during post monsoon. Further, anaerobic compartments such as septic tanks and ABR function well only when the sludge is filled no more than 2/3^{rds} of its capacity (Kurniawan et al. 2016). Constructed wetlands function efficiently only when there is a uniform distribution of wastewater throughout the width of the bed and regulated water level in unclogged filter media (Sasse 1998). Thus, absence of regular desludging of septic compartment, inflow of stormwater into the systems, channelized flow and short circuit of wastewater in a constructed wetland in municipal and community systems has reduced its removal efficiency.

SHORTCOMINGS FOR SUSTAINABLE MANAGEMENT OF SSSs

Top to down approaches used for the initiation of sanitation systems at community/municipal level overlooked the views, expectations and plans of the local community during the conception stage of the program. Furthermore, the users were not involved in selecting a technology which best fits their requirements. This dissociated the users from the program and as a consequence, they were less committed to the interventions.

SSS has been built using simple and low maintenance technology. This has often led to the misunderstanding that SSS systems are self-operating units that do not require any O&M. Thus, a minimal information on the system is sought and provided to the management entity. The consequences are reflected in the least prioritization of appointing trained caretakers, lack of monitoring guideline and formulating plans for regular O&M. Shortages of financial resources for regular O&M and major repair of the different components essential for sustainable operation in most of community/municipal systems has led to poor physical condition of the systems.

Detailed O&M manuals were not available in any of the systems except for certain instructions to be followed as regular cleaning of different components. Lack of knowledge on consequences of mishandling or malfunctioning of any unit to successive has been a reason for limited attention to prevent problems and promptly implement solutions in most of the systems. Due to the absence of laboratory analysis by treatment system owners or regulatory authorities, the performance of the systems has only been self-judged with certain visual observations that do not allow for a precise understanding of the effectiveness and efficiency of units.

Thus totality of these challenges has led to the non-sustained performance and reduced removal efficiency of the systems.

CONCLUSION AND RECOMMENDATION

On the basis of the study, it can be concluded that systems installed at community/municipal systems generally have a lower sustainability performance and removal efficiency as compared to institutional systems. Top-down approaches where local communities were less involved in the identification of issues and development of plans to address them, has led to lower ownership towards the systems. Lower removal efficiency of the system was result of improper O&M. Insecure financial sources for prompt repair and maintenance and overhaul of the system components has led to non-operating conditions.

Hence it is recommended that a bottom-up approach with active participation of users should be adopted for installation of the systems at community/municipal level. Detailed technological information along with operational manual should be provided to managerial entities. The capacity of caretakers should be enhanced and monitoring plans with indicators should be developed.

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