Report on Small Scale Decentralized Sanitation Scaling Up in Nepal

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Executive Summary

Small Scale sanitation system in Nepal was introduced as Decentralized Wastewater Treatment Plants (DEWATS) in 1997 at Dhulikhel Hospital. After successful demonstration, at least 67 such systems were installed in household, community, municipal, institutional and industrial context throughout the country. These were promoted and initiated by government, international developing agencies, national and international non- government organizations and private sectors to prevent of environmental pollution and improve public health.

A limited studies were conducted merely, to evaluate technical performance of the system through wastewater analysis. A holistic approach to analyze and evaluate critical success factors such as planning, design, implementation, management setup, operation and maintenance, socio-cultural aspect and financial aspect of the system for sustainable performance was not conducted. Hence the study conducted to provide evidence-based policy recommendations for improved system design and operations and maintenance to inform strategic financial decision making and, thus, accelerate access to treatment of wastewater and sludge. The specific objectives of the study were i. To explore current status of small-scale sanitation systems in the country, ii. To assess and evaluate detail socio-economic, cost-benefit and technical performance of the systems and iii. To recommend for improved regulatory framework, system design implementation and O&M guidelines.

The study was conducted through landscaping of small scale sanitation systems, questionnaire survey with management body, caretaker/operator and user from 30 selected systems along with technical observation and in-depth technical assessment of the 5 selected systems. 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 was used for evaluation and determining score on critical success factors and qualitative performance assessment. The result form qualitative performance assessment and in-depth technical performance assessment were compared to examine relation between critical success factor and removal efficiency.

The analysis and evaluation on critical success factors shows that design of only 50% of the systems were good enough. While implementation was good in 81.8% of the installations while handover process was worse. The skill of O&M personnel was good enough only in 4.5% of the system resulting improper execution of daily basic O&M activities. The problem has exaggerated with unskilled management body and lack of supervision on O&M of the system. Thus the score for wastewater treatment efficiency was good only for 33.3% of the systems based on qualitative assessment on performance. Similarly, the score for active water recovery was good for 50% of system providing opportunities for irrigation and flushing water. However, nutrient and energy recovery were least prioritized declining incentive among users and owners for additional investment to sustain and upgrade the system.

The technical assessment of the systems on removal efficiency of organic, nutrient and microbiological constituents shows that organic matters were effectively removed by the system whereas nutrient removal was not effective. The removal efficiency for microbiological containments were significant but not safe enough to direct use of the treated water. The removal efficiency of BOD, COD and TSS ranged between 66%-97%, 65%-95.4% and 86%-99.8% respectively. Furthermore, the removal efficiency of the systems were governed by critical success factors. The system with good design consideration to prevent inflow of stormwater, skilled O&M personnel, secured financial sources and executing effective basic O&M has achieved the higher removal efficiency.

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1 Introduction

1.1 Background and Rationale

Wastewater management and its associated problems evolved in Nepal since 1970 with pipe drinking water supply systems infrastructure development. It exaggerated especially in urban areas due to the high growth rate of population, disorganized expansion of infrastructures and unplanned sewerage developments (Shukla et al., 2012). Wastewater produced from the domestic routes includes grey water and black water produced for washing, cleaning, bathing and sanitary uses. Jha A.K. and et al. has cited Ellingsen 2011 that only small numbers of houses are connected to sanitary wastewater system and therefore most houses end up disposing the wastewater directly into the rivers and other water bodies. Common wastewater management practice involves discharging of untreated sewage into aquatic environments without proper treatment (Jha et al., 2014).

Early initiatives towards wastewater management begun during the 1980s with the construction of four centralized wastewater treatments located at Bhaktapur, Lalitpur and Kathmandu in the Valley. Unfortunately, all these early centralized wastewater treatment plants were either malfunctioned in the lack of proper operation and maintenance or never came to operation. Lately, in 2002 a Guheshwori Wastewater Treatment Plant was constructed to improve the water quality of a Bagmati River, the holy river which flows from religious Hindu pilgrim, Pashupatinath. The plant is currently functioning partially due to lack of regular supply of the energy and the higher influent than designed (KUKL, 2013).

In this context and understanding that the large centralize wastewater treatments plants are not feasible in developing countries, a small scale sanitation system was introduced as Decentralized Wastewater Treatment System (DEWATS). The system was promoted as environmentally friendly and locally sustainable technology. Technically and financially supported by donor agencies such systems were constructed at the community level and institutional level to demonstrate its effectiveness since 1997s. However, the present status of such systems, as how many systems have been installed, how are they being functioning and what are underlying challenges for upscaling was not clear enough. Hence, this study was designed to conduct an in-depth study on the current status of such systems and evaluate its performance.

1.2 Objectives

The main goal of the project was to provide evidence-based policy recommendations for improved system design and operations and maintenance to inform strategic financial decision making and, thus, accelerate access to treatment of wastewater and sludge. The specific objectives of the study were:

- To explore current status of small-scale sanitation systems in the country

- To assess and evaluate detail socio-economic, cost-benefit and technical performance of the systems and
- To recommend for improved regulatory framework, system design implementation and O&M guidelines

2 Methodology

2.1 Study Design

The study was designed into four distinct components such as

i. Landscape Study
ii. Basic Assessment and
iii. In-depth sampling and Laboratory Analysis

2.2 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 12 and 18 selected systems were installed in community/municipal and institutional context respectively.

2.3 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.

2.4 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.

Planning, design and implementation	**Sub-indicators**
1 - Quality of design	Correct system sizing for the context, wastewater source or variability, stormwater. Assumptions, design errors. Designed for accessibility (reactors/desludging / sampling). Potential nuisances taken into account in design

2 - Quality of implementation	Construction quality, quality of materials, quality of work, quality of supervision, completeness of construction, installation errors, consent of establishment
3 - System startup and handover	instructions, manual and project documentation (e.g. flow sheet) given to future owner, support after handover
Operation and maintenance	
4 - Skills of personnel	Operator is existent (if not nap), operator(s) can do what he is supposed to do, identifies problems, and has knowledge about the system. Ability to solve problems also counts as skill (but cannot necessarily be expected, depending on problems and definition of responsibilities)
5 - Motivation of personnel	Operator is existent (if not nap), operator wants to do a good job, even if he doesn't know what to do and how, site is clean, happiness of operator. Operator is present when he is supposed to be present.
6 - Accessibility of maintenance services	Operator and/or manager know whom to contact and how to organize required maintenance tasks (e.g. desludging, repairs, replacements). The required outsourced services and expertise are locally available.
7 - Availability of energy and chemicals	energy and chemicals available as needed for the process, sufficient stock of fuel and chemicals
Management and monitoring	
8 - Skills of management entity	management entity can do what it is supposed to do, identifies problems, can provide good answers why things are done this way, has knowledge about the system
9 - Supervision of O&M activities	operators are correctly instructed and know what tasks they have, their work is supervised, maintenance tasks are scheduled, Training of Operator (and by whom)
10 - Human Resources Management	sufficient number of operators is always available, adequate working hours and salaries
11 - Documentation	performance and finance information are documented and available when needed

Socio-cultural aspects	
12 - User behaviour	Users are correctly instructed (e.g. what not to throw into the toilet - solid waste, chemicals). They actually behave correctly. The user behaviour doesn't negatively affect the system.
13 - User satisfaction	Users accept the system (incl. reuse). Users like the system and don't reject it. Complaints (if any) are addressed
Finance	
14 - O&M cost recovery	Costs are covered (no matter how high they are) by generating the required income. Money is put aside also for long-term maintenance activities. User's ability to pay is not overstretched.

2.5 Wastewater Sampling and Laboratory Analyses

Five operating small-scale sanitation systems were selected based upon the representation of a variety of technology combinations and context of the application. The composite samples were collected with two-hour intervals for 24 hours at influent and effluent. In case of multiple influents and effluents, samples were collected in containers from each source and their respective flow rates were measured. All the collected samples were properly mixed until the sample became homogenous. The samples from each point were then mixed in a single container in proportion to their flow rate. In case of small flow, the sample was collected for continuous 20 minutes and the volume of the collected sample was measured.

After 24 hours, 12 samples each at influent and effluent were mixed according to their respective flow rate in order to prepare the two composite samples. The field parameters were measured from these composite samples. At least two litres of samples were collected (bigger volumes were collected in case of additional grab samples) for final compositing. Once per sampling round at 8 pm, grab samples were collected at the inlet of each treatment component as well as at influent and effluent. Four additional grab samples at influent and effluent were collected (at 2 am, 8 am, 2 pm and 8 pm) in order to capture daily variations.

Measurements of pH, temperature, electric conductivity (EC), turbidity and dissolved oxygen were carried out onsite using pH meter, EC meter, turbidity meter and Azide modification method respectively. Samples were transported to ENPHO lab, Kathmandu for the analysis of remaining parameters such as total and soluble chemical oxygen demand (COD), biochemical oxygen demand (BOD), total phosphorus (TP), total nitrogen (TN), ammonia-nitrogen (NH_4-N), oil and grease and faecal coliform (FC). Duplicates analysis were performed for all parameters.

3 Small Scale Sanitation Systems in Nepal

3.1 History of Small Scale Sanitation Systems

Small Scale sanitation system in Nepal was introduced as Decentralized Wastewater Treatment Plants (DEWATS) in 1997 at Dhulikhel Hospital. The plant consists of settler and constructed wetlands that treat wastewater by the combination of anaerobic biodegradation and aerobic filtration through filter media compacted in the constructed wetland. Similarly, in 2002 the first community-level wastewater treatment system was constructed in Sunga, Madhyapur Thimi located in Bhaktapur District to demonstrate that the technology can effectively treat wastewater from the community. Thereafter in total 67 systems have been installed throughout the country.

3.2 Number, Types and Context of the Systems Installed

At least 67 small-scale decentralized sanitation systems have been installed in Nepal. These systems were applied in a different context such as to treat wastewater from household, institution, community, hospital, hotel and municipal level. The table 3-1 presents descriptions of a number of systems and context of the application.

Table 3-1: Descriptions of Context and Number of SSSs

S.N.	Context of Application	Total Number
1	Community/Municipal Level	19
2	Household	11
3	Institutional	15
4	Hospital	8
5	Hotel	3
6	Industrial	5
7	Housing Colony	3
8	Fecal Sludge Treatment	3
	Total	67

These systems were installed in the central, eastern and western region in 14 districts located in Tarai and Hilly areas of the country.

3.3 Implementing Bodies of the Systems

Environment and Public Health Organization (ENPHO) introduced small-scale sanitation system. Initially, the system was constructed at an institution such as Dhulikhel Hospital, Sushma Koirala Memorial Hospital, ENPHO building and Malpi School as a demonstration site for promotion of the system. Particularly, UN-Habitat in its Water For Asian Countries (WAC)- Nepal programme promoted community-level sanitation systems, to demonstrate innovative initiatives on water and sanitation sector which can be scaled up to meet Million Development Goal (MDG) target at the local level.

Government initiative small-scale sanitation systems were constructed under implementation of Bagmati Action Plan and Urban and Environmental Improvement Project (UIEP). The High Powered Committee for Integrated Development of Bagmati Civilization (HPCIDBC) has constructed a small scale sanitation system upstream of the Bagmati River to prevent river pollution.

Under Urban and Environmental Improvement Project (UEIP) in its sanitation and waste management subproject. UEIP was implemented by the Government of Nepal (GoN) with a financial assistance of Asian Development Bank (ADB) during the period 2003 to 2009. The executing agency for the project was Ministry of Physical Planning and Works (MPPW) through Department of Urban Development and Building Construction (DUDBC). The executing agency DUDBC established a Project Coordination Office (PCO) to support and manage the execution of the project at the centre under the guidance of the Project Steering Committee (PSC). The implementation activities in the municipality were taken by the Project Implementation Unit (PIU) membered by representatives of DUDBC, municipality and users. The main objective of the project was to facilitate sustainable urban development by addressing critical environmental needs. Besides, private consultants and companies were engaged in the design and construction of the systems. The table 3-2 lists some of the implementing bodies of SSSs.

Table 3-2: Implementing Bodies for Installation of Small Scale Sanitation Systems

Government Bodies	International Development Agencies	Non-Government Organizations	Private Companies/Consultants
• Ministry of Physical Planning and Urban Development (MPPUD) • Department of Building Design and Construction (DBDUC) • High Powered Committee for Integrated Development of Bagmati Civilization (HPCIDBC)	• Asian Development Bank (ADB) • DANIDA • UN-Habitat • Water Aid • UNESCAP • EAWAG • CDD BORDA	• Environment and Public Health Organization (ENPHO) • Lumanti • Center for Integrated Urban Development (CIUD) • SOMNEED	• NIVA RAIN • Motherland Group of Energy • Autark Engineering AG • Building Design Authority (P) Ltd • Integrated Consultants Nepal (P.) Ltd. • Welink Consultants P Ltd. • Architect's Design Associates

			• TAEC Consultant

4 Result on Assessment of Sustainability and Technical Performance

4.1 Result of Qualitative Assessment

4.1.1 Planning, design and implementation

The most common sanitation options and practices were either installation of septic tanks or direct discharge of wastewater into nearby water resources through conventional sewer system. This has increased pollution of water resources and increased threats to human health. Thus, most the systems were planned and installed to protect the environment (EP) particularly protection of water resources. Similarly, water reclamation (WR), energy generation (EG) and diseases preventions (DP) were tight up together with environmental protection. 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. Also, they were involved in the selection of a site for construction of a system either through direct interaction or through nominating representatives in a planning committee.

The result on critical success factors assessment on planning, design and implementation is shown in the figure 5-1. It shows that design were good only in 50% of the systems. The implementation were good in 81% while handover process need additional caution at 45% and insufficient in 22.7%.

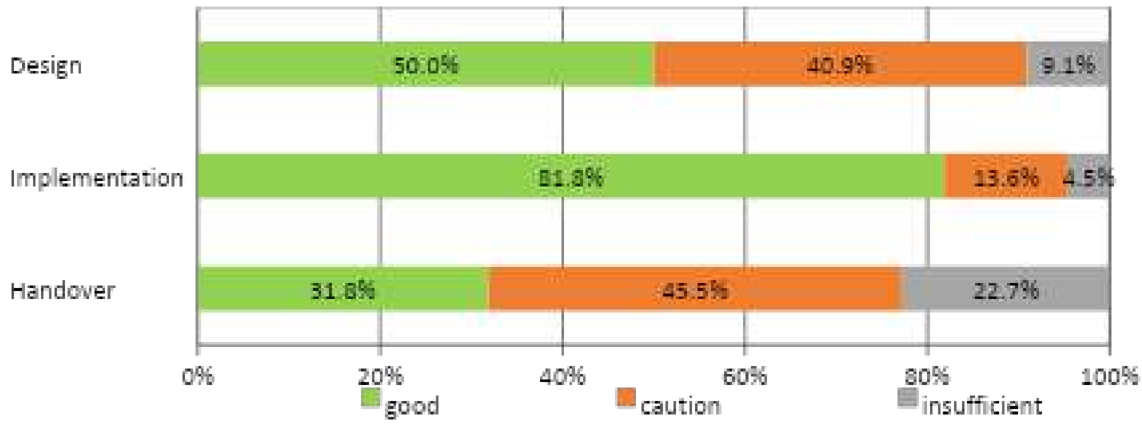

Figure 5-1 CSF Result on Planning, Design and Implementation of the Systems

Design consideration such as installation of separate storm water drainage and management were followed in 24 (80%) systems. Sludge treatment facilities were inbuilt in 10 (33.3%) systems while 18 (60%) systems without such facilities were accessible to desludging vehicles. Similarly, precaution on 15 (50%) systems were adopted to prevent smell nuisance. The most important factor that, all users get connected to the systems were not fulfilled in 16 (53.3%) systems. The most common reasons were households locating below the sewer network, too far from the system and unwillingness of household to connect. Also, in 19 (63.3%) systems opportunities to reuse treated wastewater were overlooked in its design.

The majority of the systems were constructed under direct supervision of specialized designer by general contractors or community. Observation of 24 (80%) systems without cracks and 20 (66.6%) systems without any relevant corrosion of concrete or metal parts or other damage structure shows that quality of building materials were maintained. Further, adverse conditions of manholes were not observed in 25 (83.3%) systems. However, 9 (30%) systems have changed or correction implemented retrospectively. The major challenges during implementation were finding the appropriate land and unwillingness of users to assist for construction particularly in community/municipal systems initiated by government or donor agencies.

Development of operational manual and guideline, formation of operations and maintenance fund and capacity buildup of caretaker/operator are essential for sustainable performance that should be considered prior to handover of the systems by designer and constructor. While general information on what to discharge and not were provided to user in 17 (56.6%) systems.

4.1.2 Operation and Maintenance

The result for CSF assessment of operation and maintenance of the systems is shown in figure 5-2. Skills of O&M personnel was insufficient and need caution in 41% and 50% of the systems respectively. However, there was good motivation for caretakers/operators in 50% of the systems. Good maintenance services were available in only 13% of the systems and others requires improvement though sufficient energy and consumables for daily operation of the systems were available.

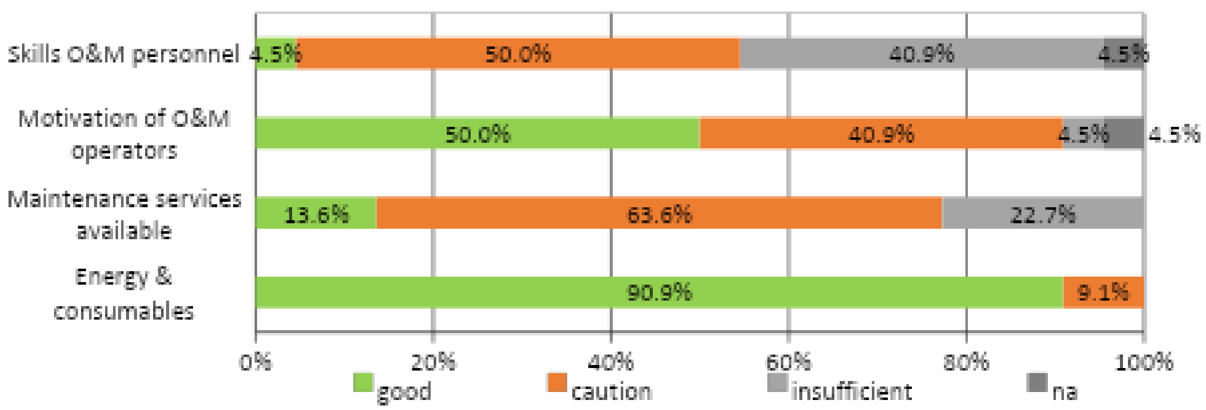

Figure 5-2: CSF Result on Operation and Maintenance of the Systems

The social and environmental unit or similar units was responsible for daily operation and maintenance of wastewater treatment plants which it executes through appointed designated caretakers. Thus, in overall designated caretakers or operators were responsible for daily O&M in 9 (75%) community/municipal level systems while in other remaining systems labours were mobilized under the direct supervision of the managerial body. At institutional level systems skilled technical staff from either technical and maintenance unit or similar unit was responsible for daily O&M in 10 (55.5%) systems. While in other systems general staff such as watchman, gardener and helpers were mobilized as per requirements.

The majority of caretakers in community/ municipal level systems were a construction worker who stayed and took the job after completion of the building. In few cases, local inhabitant or community member without experience and training in wastewater management were appointed. Caretakers from 5 (41.7%) of community/municipal systems were capable of functioning daily O&M activities without any guidance such that they were capable to discover, solve and prevent problems. Contradictorily, only caretakers from 3 (25%) systems have received basic training in daily operation and maintenance. At institutional level systems, nine among ten caretakers mobilized from technical and maintenance unit or similar unit was capable of discovering, resolving and preventing the problems without external guidance. Before taking over the job, only three of them have experienced in wastewater management and later on six caretakers have received training on basic O&M of the systems.

The motivation of O&M personnel were measured through observation of cleanliness of site, orders of equipment, overgrowth plants, excess scum layer and plastic wastes in pretreatment units. It was observed that, 22 (73.3%) systems were either very clean or clean. Similarly, the equipment in the site was arranged tidily in 17 (56.6%) systems and no overgrowth of plants were observed in 16 (53.3%) systems. While there were no significant scum layer and excess accumulated plastic waste in only 8 (26.6%) and 10 (33.3%) systems respectively.

Replacing pipes and fittings, cleaning the clogged pipes, emptying the septic compartment, cutting excessive reeds and cleaning the clogged filter media were irregular task which requires additional resources. The majority of systems have endowed right with managerial body to purchase spare parts and are easily available in local market. Also, external services such as plumber, private septic tank emptier, seasonal labour and other required materials are easily available but majority of systems were constraint to financial support. Thus, financial mechanism has to be improve for obtaining maintenance services. Whereas since, low cost and low maintenance technology were applied in most of the systems, energy and consumables were easily accessible.

4.1.3 Management Setup

Management setup was different according to the context of the systems. Systems at institutional level were managed by managing a body of the institution. While, in institutions like hospitals and hotels, separate technical or maintenance unit was given overall responsibility. Community-Based Organizations (CBO) membered by users were formed in the community level systems for its management. The municipal level systems were managed in coordination between physical planning and environmental unit of the respective municipality.

The result on CSF assessment of management setup is shown in the figure 5-3. It shows that skill of management body is good only in 22.7% of the systems while rest requires improvement and capacity buildup. The supervision of management body on O&M were good only in 9% and good human resource management exist in only 6% of the systems. While documentation of necessary information was recorded in only 31.8% of the systems.

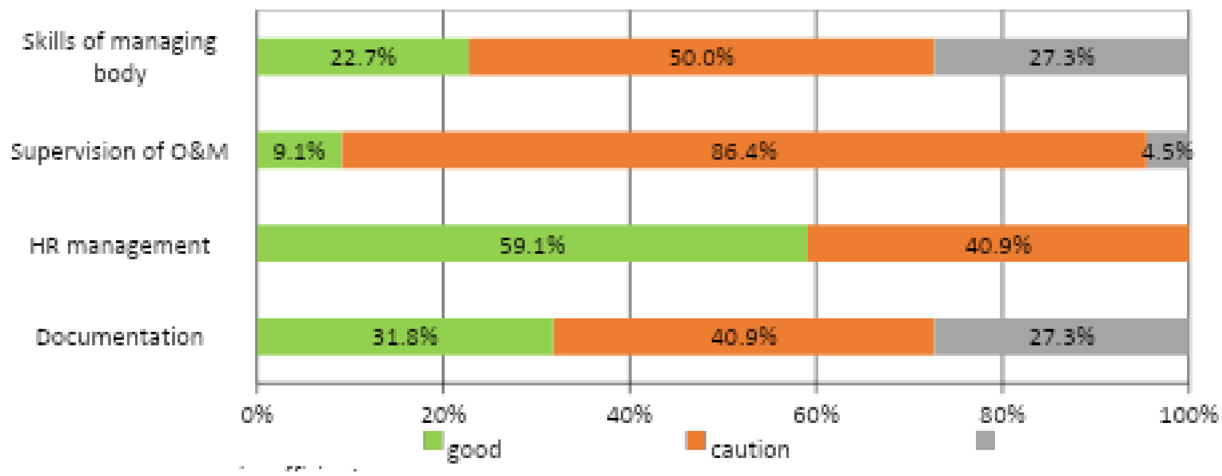

Figure 5-3: CSF Assessment Result on Management Setup of the Systems

Executing regular operational tasks, financial management and organizing repair and maintenance of the system were major duties of management body of systems installed at the institutional level. Besides these, managing complaints from users, approving a new household connection to the system and report keeping of caretakers were additional duties of management bodies of the community/municipal systems. However, monitoring of the performance of the systems through wastewater quality analysis was not performed. Members or management body of 14 (46.7%) systems have received training on wastewater management. Managers or management body from each 7 systems in community/municipal and institutional systems were trained. Particularly training on the daily operation of the system is provided by either project manager or engineer involved in designing during the start of the operation.

Daily performance assessment of the system was carried out only in 9 (30%) systems through visual observation of the physical condition. Wastewater quality was not monitored in almost all the systems. The presence of caretakers/operators in the system was monitored through logbook or regular supervision. The human resource management was lacked in most of the systems. Generally, most of the caretakers/operators does not go for vacation. The amount of salary paid to caretaker varies with respect to systems whether it is community/municipal or institutional level.

4.1.4 Socio-cultural Aspects

Socio-cultural aspect towards the systems were assessed through user behavior and satisfaction. The CSF assessment on socio-cultural aspects is shown in the figure. The behavior of users towards the system is good only in 18% of the system and was not applicable in 9% of systems while rest need additional caution. However, users from 50% of the systems were satisfied with the technology and performance of the systems.

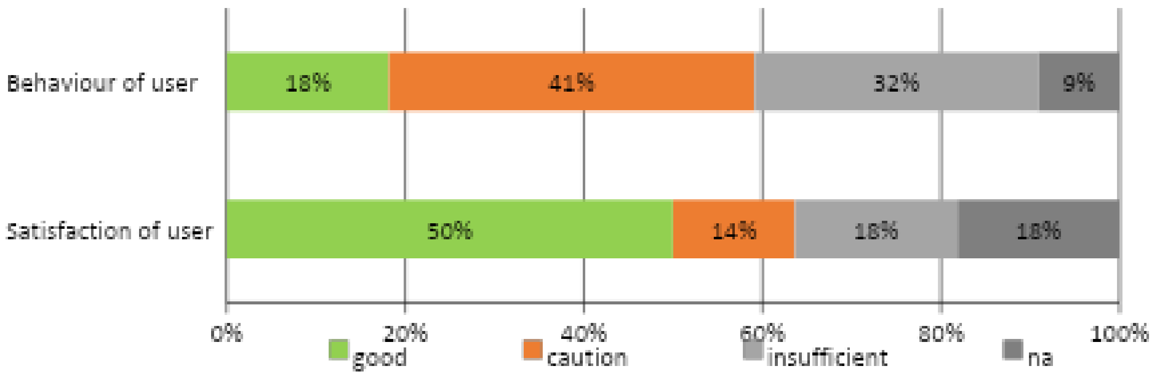

Figure 5-4: CSF Assessment Result on Socio-cultural Aspect of the Systems

The accumulation of excessive solid wastes particularly, plastics in the system shows they were not following the instructions. Unwillingness of users to pay service charge and other O&M charges indicates the users has to be educate on importance of the systems and their roles for its operation. Satisfaction of users as assessed shows that environmental protection and eco-friendliness were most liked features of the system. Foul smell, files and insects around the systems was most disliked features. Complaints on these disliked features have registered in only 8 systems. Maximum user 11 (46%) ranked installed technology as good options and in an average good performance though there also exist both responses on two extreme sides as excellent and very bad. Reuse of treated wastewater for irrigation and gardening was perceived as good by the 67% of users.

4.1.5 Financial Aspects

Financial records of systems were generally recorded through maintaining logbooks and regular reports in the community and municipal systems. Expenses were generally made through the financial department of a municipality under the maintenance and miscellaneous budget head. Thus disintegrated financial data was not obtained in most of municipality managed systems. While in CBO managed systems, there was the provision of presenting financial records at an annual general meeting of user's committee. However, in only 2 systems, approval of financial statement from user committee was practiced. In the institutional system, expenses for operation and maintenance of systems were comparatively very low as compared to total expenses under maintenance budget head. Also since there was no distinguished caretaker appointed for the operation and maintenance of only wastewater treatment system, salary provided to such caretaker was recorded under different headings. Hence the majority of systems at this level does not have recorded documents on expenses particular to the system.

Planning regular budget for major expenses, uncertainty and emergencies were not practiced in 26 (87%) systems. However, there was the provision for allocating budget for the systems in few municipal/community systems that are spent on caretaker's salary. In some institutional systems, the budget was allocated only after the system required maintenance and repair.

A major source of revenues in community/municipal system was service charge collected from the users. Beside it, one system has additional minimal source generated from the sale of biogas. 58% of communal and municipal systems have been collecting a regular service charge from users. These fees are defined per household connection to the system. Whereas in municipal level systems, wastewater service tax from users was either collected separately or included in collective tax according to Local Self Governance Act, 1999.

Service charges have been fixed as a flat system and progressive tariff systems in community and municipal system. In most of the community-level system, there was a flat system for service charged based upon household connection. Service charge ranged from minimum Rs. 200 per year to a maximum of Rs. 600 per year. Beside this, communal systems with integrated biogas plant have an additional service charge of Rs. 500 per month per household for biogas connected household. While in that system where progressive tariff systems were introduced, the area covered by building connected to the system and economic status of households were considered. It was observed that one of a municipality with progressive tariff system based on area covered by building has a minimum rate of Rs. 150 to maximum Rs. 300 per month. The fee has been increased by 25% since the operation of the system. Similarly, a system based on economic status of household connected to the system as practised by wastewater system managed by joint management committee from municipality and user's representatives have service charge range from Rs. 90 to maximum Rs. 240 per month.

These service charges for wastewater treatment were collected monthly in municipal level systems whereas in community-level systems charges were collected annually. Also, comparatively these service charges were lower than monthly minimum average service charges for drinking water. The monthly average minimum charge for drinking water was Rs. 160 per month. Despite being lower service charges, it was revealed that collection of service charge was not easy, as there was a delay in payment and some users do not want to pay it.

Total expenses for operation and maintenance of systems can be categorized as regular operational cost including salary of caretakers, other indirect cost such as electricity charges for operating pumps, cost involved in organizing meetings in the case of community/municipality level, and irregular expenses such as cost for desluding, repairing, cleaning of filter media which does not occurs regularly.

It was found that 14 (47%) of managers have knowledge on recurring expenses for regular O&M while 43% of them does not have any idea about it. Also, 3 (10%) of them responded that there were no any expenses for systems. The average regular operating cost (including a salary of the caretaker) for the municipal system is highest as compared to the community and institutional systems. Contradictorily, the maximum regular operating cost was found in community-level sanitation system with Rs. 20000 per month. The average regular operating cost for different context is shown in table 5-1.

Table 5-1: Average, minimum and maximum operating cost

Context	Regular Operating Cost (Rs. per month)		
	Average	Maximum	Minimum
Community	7340	20000	1500
Municipality	8500	14000	3000
Institutions	3925	10500	300

Similarly, the average salary given per caretaker was highest at institutional level sanitation system and lowest at community level system. The average salary for the caretaker in different contexts sanitation system is shown in table 5-2.

Table 5-2: Status of salary provided to caretaker

Context	Salary (Rs. per month)		
	Average	Maximum	Minimum
Community	3200	6000	1500
Municipality	4500	6000	2000
Institutions	13000	20000	9000

Cost for removal of sludge from septic compartment varies with respect to the context and size of the septic tank. It was observed minimum Rs. 3000 is required for desludging the sludge at institution level while maximum Rs. 36000 was required for community-level systems. Major repair activity carried out were diverting grey water or stormwater away from systems, cleaning and replacing of filter media. The cost for such activity ranges from Rs. 500 for cleaning of grease trap to maximum cost occurring at Rs. 21000000 for cleaning and replacing filter media in the municipal level wastewater treatment plant.

Thus the CSF assessment result for financial status on cost recovery of O&M shows good for 73% of the systems while rest need improvement as shown in the figure.

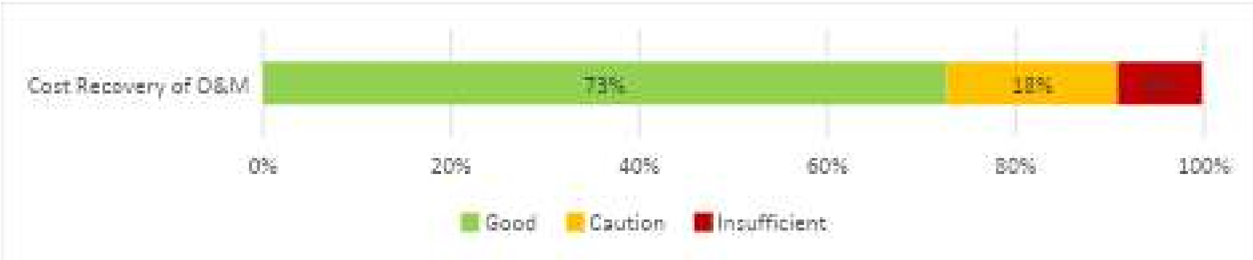

Figure 5-5: CSF Assessment Result of Financial Aspect of the Systems

4.2 Result of Performance Assessments

4.2.1 Qualitative performance judgment for 30 systems

Qualitative performance judgment for 30 systems on wastewater treatment is shown in the figure5-6. It shows that effluent quality was good for 10 (33.3%) systems and were in caution or insufficient for other remaining systems measured based upon visual observation and pH of the effluent. Similarly, only 7 (23.3%) systems has good loading of the wastewater while majority 15 systems have insufficient loading of wastewater.

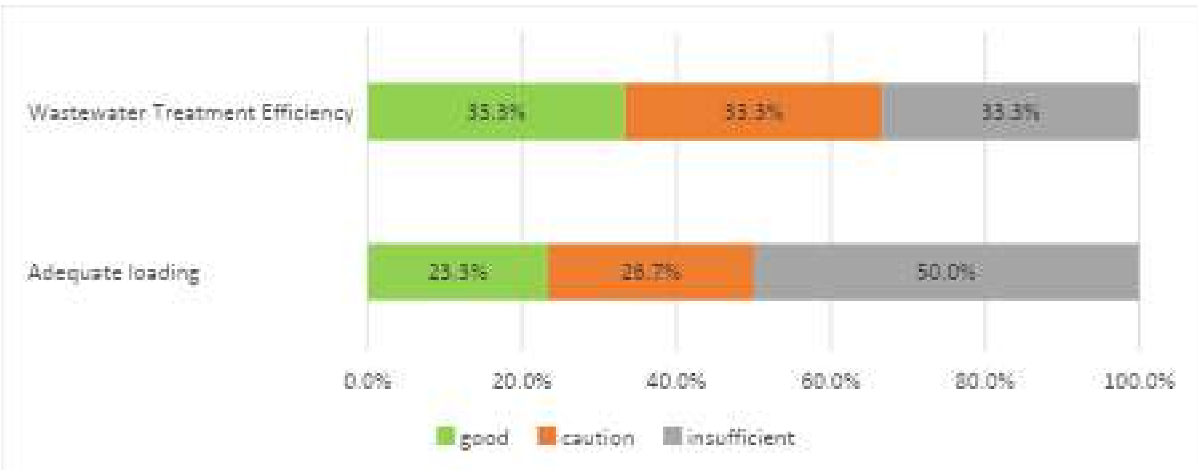

Figure 5-6: Result on Qualitative Performance Judgment of 30 Systems

Qualitative performance judgment for reuse of resources from systems is shown in the figure 5-7. It shows that 15 systems were reusing treated water in irrigation or gardening as per the design while 10 systems were not designed for reuse of treated wastewater. Application of treated sludge was practiced in only one system. Energy recovery mechanism were inbuilt in 6 systems while good functioning was observed in only one system whereas majority 4 systems required caution.

Figure 5-7: Qualitative Performance Judgment on Reuse of Resources in 30 Systems

Qualitative performance judgment on solid management result shown in figure 5-8 shows that regular removal of plastic waste, scum layer and desludging was practiced in only 2 (6.7%) of the systems while majority 90% of the systems has insufficient activities on it.

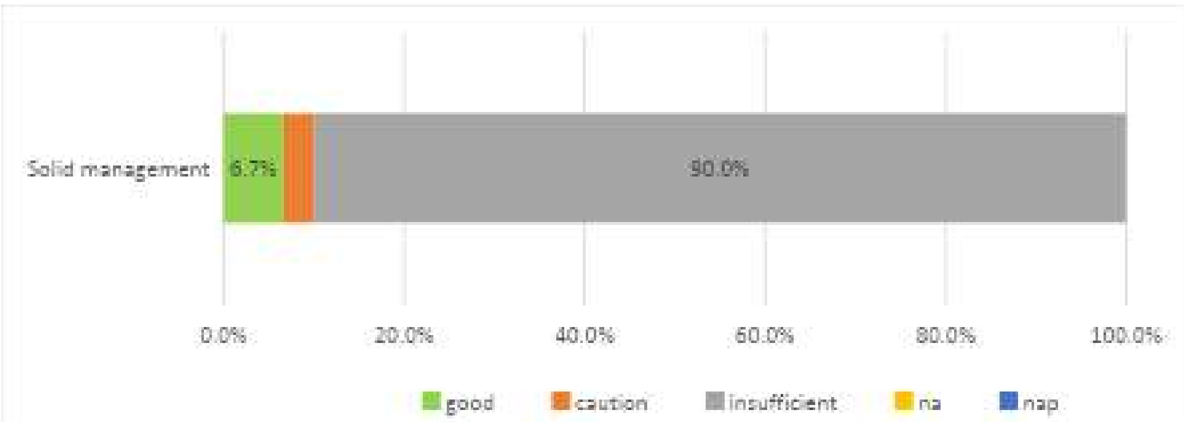

Figure 5-8: Qualitative Performance Judgment Result on Solid Management

The qualitative performance judgment result of five systems selected for technical performance assessment through wastewater analysis is shown in figure 5-9. It shows that, wastewater treatment efficiency and active water recovery were good while nutrient and energy recovery were worst and lack solid waste management.

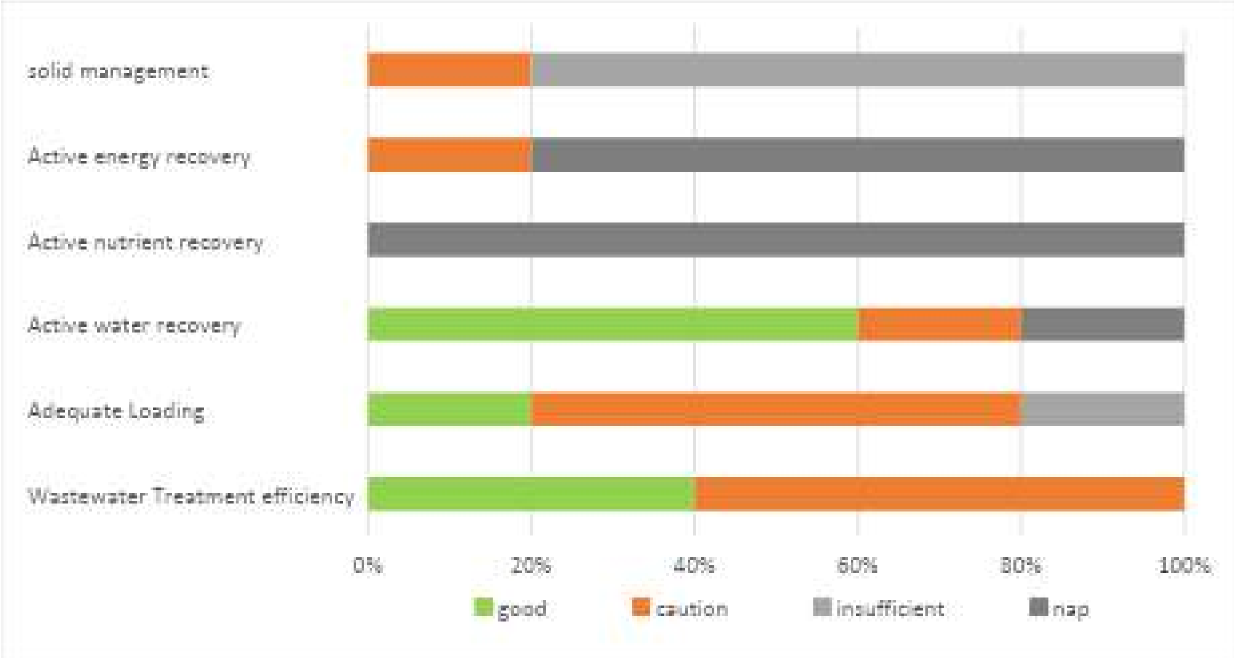

Figure 5-9: Qualitative Judgment Result for 5 systems selected for In-depth Performance Assessment through wastewater Analysis

4.2.2 Results of the Performance Assessment of 5 Systems through Wastewater Analysis

4.2.2.1 Short Description of Context and Inbuilt Component of Selected Systems

Table 5- presents short descriptions on context and components inbuilt in each selected systems.

Table 5-3: A short description of context and components of selected system for in-depth technical assessment

S.N.	Code	Context	Components
1	4S-020-N	Community Level	Biogas Digester_6 Parallel Horizontal Flow Beds (HFBs)
2	4S-002-N	Municipal Level	Septic Tank-Anaerobic Filter (AF)-2 Parallel Horizontal Flow Beds
3	4S-004-N	Institutional (Hotel)	Integrated Septic Tank with Anaerobic Baffle Reactor –Horizontal Flow Bed
4	4S-005-N	Institutional (Hospital)	Septic Tank-Horizontal Flow Bed-2 Vertical Flow Beds in series

5	4S-009-N	Institutional (School)	Integrated Septic Tank with Anaerobic Baffle Reactor –Horizontal Flow Bed – Vertical Flow Bed –Polishing pond

4.2.2.2 Results of the performance of 4S-020-N

a. Physical condition and parameters during three Round of Sampling

There was continuous flow for 24 hours in the system during a 1st and 3rd round of sampling while no measurable flow between midnight 12 to 4 AM in the 2nd round of sampling. The average inflow were 1.6l/sec, 0.19l/sec and 0.23 l/sec for three consecutive round. Similarly, the average pH values ranged from 7.7 -8.1. The minimum and maximum average turbidity (27.34 NTU and 483 NTU) and average electrical conductivity (619 µS/cm and 2640 µS/cm) both were measured during the 1st and 2nd round. The average outflow for three round of sampling was 2.1 l/sec, 0.23 l/sec and 0.19 l/sec respectively. The average pH values ranged from 6.75-7.82 for. The lowest and the highest average turbidity was 8.43 NTU and 86 NTU during a 1st and 2nd round of sampling. Similarly, the lowest average electrical conductivity was 450 µS/cm and the highest 3033 µS/cm were measured during that time.

The accumulated sludge in the biogas digester was not removed till 2nd round of sampling since its operation in 2008 AD. Excess scum flow from it, to distribution tank, was observed after sludge removed during the 3rd round of sampling. The pH values of wastewater discharged into distribution tank from the digester were 7.32, 7.39 and 7.8 for three consecutive sampling. The turbidity and an electrical conductivity were lowest during 1st round at 19.56 NTU and 664 µS/cm. While both parameters were above 200 NTU and 1900 µS/cm for rest of samplings.

Two horizontal flow constructed wetlands were totally covered with silts due to inundation during flood before a month of the 1st round of sampling. Thus, only four out of six horizontal flow beds were operational. Among these, two beds have numerous green reeds while other remaining was covered with weeds and ponded with an inflow of water from surrounding paddy field. All of these beds contained swivel pipe but there was leakage beneath it. During 2nd round of sampling, only two HFBs were operational with numerous dried reeds and remaining beds were under maintenance. While in the 3rd round of sampling, two HFBs with cleaned filter media were operational with scarce reeds.

b. Concentration and Removal Efficiency of various parameters

The BOD and COD concentrations were in the range of 103-888 mg/L and 203-1823 mg/L respectively. The suspended solids concentration in the raw wastewater was in the range of 56.5-2035 mg/L as shown in Figure 5-10. The raw wastewater concentration is at slightly higher than the earlier reported value for the Nepal region by Singh et al., 2009 and was in good agreement with Zhang et al., 2015. The treated water has a BOD of 35-285 mg/L, COD of 72-508mg/L and TSS of 8.0-210 mg/L. It was observed that the removal efficiency of the organics and solids was; 66-68% for BOD, 65-72.1% for COD and 86-90% for TSS removal. It showed that the system was very effective during the 3rd round of the sampling as compared to other rounds. The effectiveness was most probably due to uniform distribution of inflow over the full width of the inlet zone of constructed wetland with cleaned filter media. Similarly, in the 2nd round of sampling, less efficient as compared to 3rd round is most probably due to channelized inflow in a clogged filter media and dried reeds. Whereas during the 1st round of sampling inflow of water from paddy field, ponded horizontal bed and excesses weeds have reduced overall efficiency however concentration was low as a result of dilution with inflowing water.

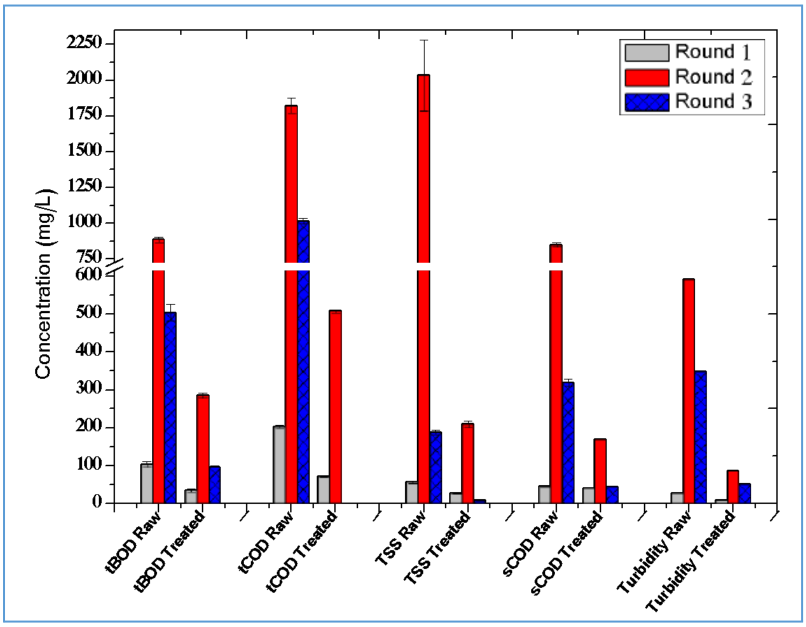

Figure 5-10: Organics and solids concentration in raw and treated composite wastewater during different sampling rounds for 4S-020-N

The nutrients level in the raw wastewater was (TN – 24.5-244 mg/L; AN – 19.3-204 mg/L) and total phosphate (2.4-31 mg/L) (Figure 5-11). The TN value in the treated water was in the range of 17.8-263 mg/L and TP value in the range of 2-29.5 mg/L. Similar to organics and solids, nutrients (AN and TN) concentration was higher in the second round of sampling, the reason was that the reeds in the HFB were clogged and reeds were dried and only two HFBs were working.

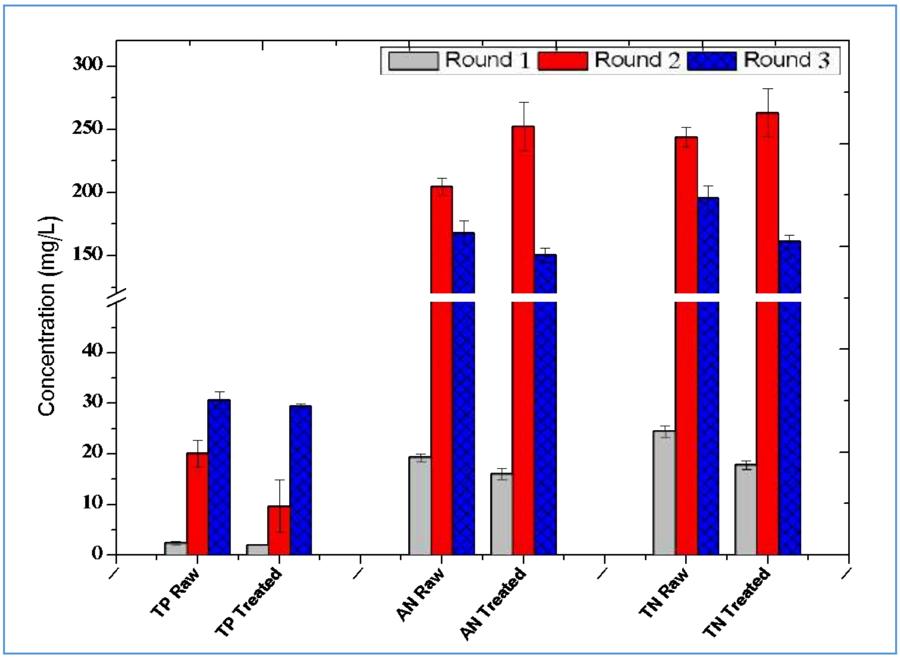

Figure 5-11: Nutrients Concentration in raw and treated composite wastewater during different sampling round for 4S-020-N

The faecal coliform level in the raw wastewater was in the range of 2.4E6 to 2.4E7 and it was reduced to 2.4x10^6 to 2.4x10^7 with 1 log reduction in the treated water (Figure 5-12). The faecal coliform removal was also affected in the second round of sampling campaign, with <1 log reduction.

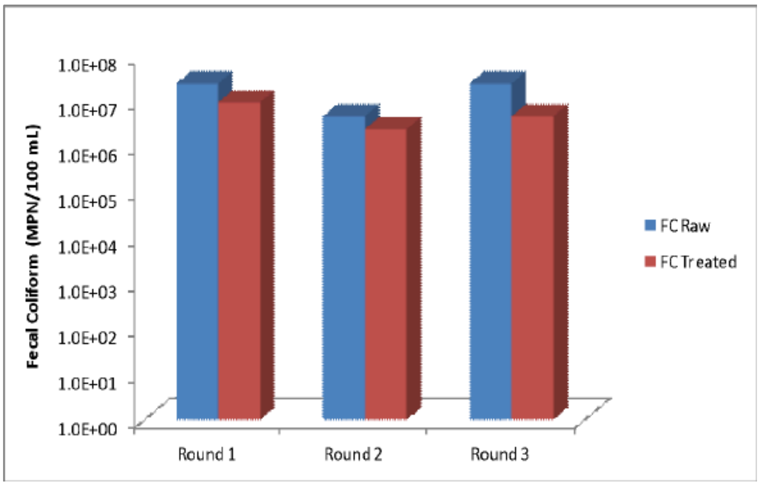

Figure 5-12: Faecal coliform concentrations in raw and treated composite wastewater for different sampling round for 4S-020-N

4.2.2.3 Results of the performance of 4S-002-N

a. Physical condition and parameters during three Round of Sampling

There was continuous flow for 24 hours in the system throughout all sampling round. The average inflow was 0.63 l/sec, 0.35l/sec and 0.79 l/sec for three consecutive rounds of sampling. Similarly, the average pH values ranged from 7.45 -7.83. The minimum and maximum average turbidity (174 NTU and 313 NTU) and average electrical conductivity (1373 µS/cm and 1784 µS/cm) both were measured during the 1st and 2nd round. The maximum average outflow 0.72 l/sec was observed during the 3rd round of sampling and minimum average outflow was 0.30 l/sec during the 2nd round of sampling. The average pH values ranged from 7.5-7.7. The lowest and the highest average turbidity was 9.5 NTU and 18 NTU during a 1st and 3rd round of sampling. Similarly, the lowest average electrical conductivity was 1185 µS/cm and the highest 1790 µS/cm were measured during the same time.

The accumulated sludge in the septic tank was not removed since its operation in 2010 AD. The pH values of outflow from the septic tank into Anaerobic Filter (AF) was within 7.05-7.25 for three consecutive samplings. The turbidity and an electrical conductivity were lowest during 1st round at 30.5 NTU and 1183 µS/cm. While the maximum turbidity was 75.3 NTU during 3rd round and 1810 µS/cm of electrical conductivity during the 2nd round of sampling.

The pH value of outflow from AF was 7.22-7.58 throughout all round of samplings. The minimum and maximum turbidities were 31 NTU and 63 NTU in the 3rd and 2nd round of sampling. Similarly, the minimum and maximum electrical conductivity were 1282 µS/cm and 1820 µS/cm during a 1st and 2nd round of sampling. Horizontal flow constructed wetlands were unclogged throughout all round of sampling. During 1st round, there were numerous and green reeds along with other weeds on the bed which was trimmed during a 2nd and 3rd round of sampling. The major defect in the HFBs was unleveled inflow distribution pipe and there was no uniform distribution of inflow over all the width of inlet zone. Also, swivel pipe connected to the HFBs were not correctly positioned.

b. Removal Efficiency

The BOD and COD concentrations in raw wastewater were in the range of 210-465 mg/L and 425-944 mg/L respectively. The suspended solids concentration in the raw wastewater was in the range of 146-588 mg/L as shown in Figure 5-13. The treated water has a BOD of 33-106 mg/L, COD of 74-215 mg/L and TSS of 7.8-22.5 mg/L (Figure 5-9). The removal efficiencies of organics and solids were found to be 77.2-84.2% for BOD, 77-83% for COD and 95-96% for TSS. The maximum removal of organics and solids were seen during the 2nd round of in-depth sampling, as it was seen from the sampling campaign that the reed beds are having densely grown plants without other weeds.

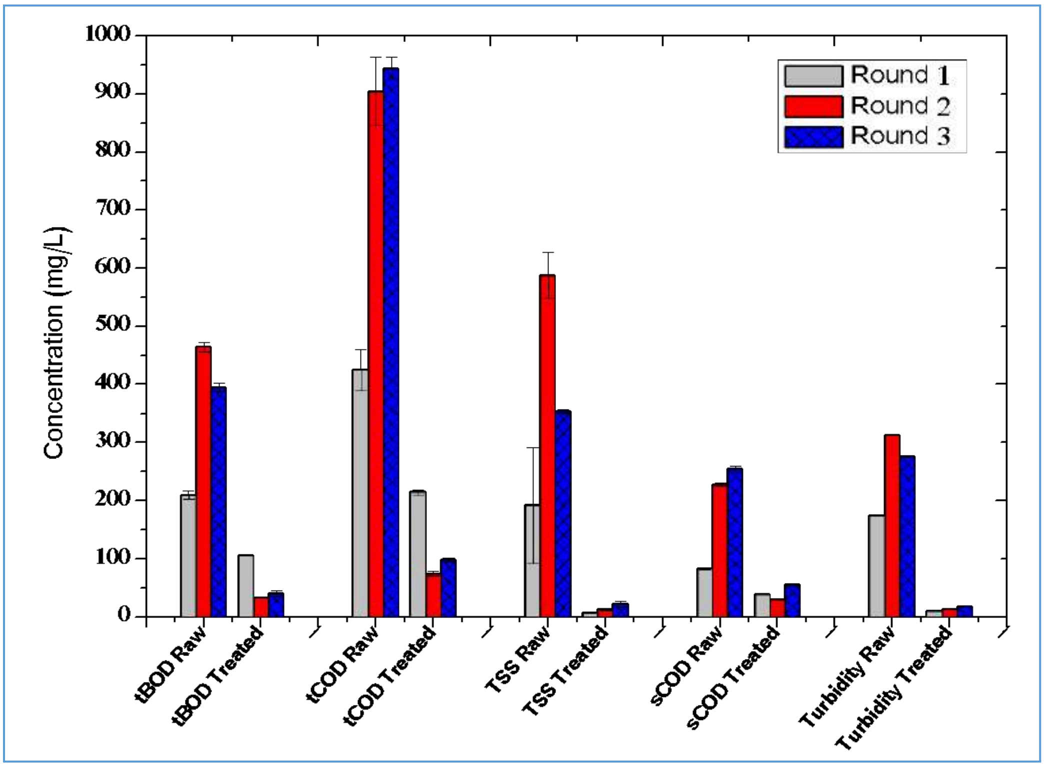

Figure 5-13: Organics and solids concentrations in raw and treated composite water during different sampling campaign for 4S-002-N

The nutrients level in the raw wastewater was found to be; Total nitrogen (TN) – 72-158 mg/L; Ammoniacal nitrogen (AN) - 64-128 mg/L and total phosphate (TP) - 7.5-12.9 mg/L (Figure 5-14). The TN value in the treated water was in the range of 68.4-131 mg/L and TP value in the range of 7.2-10.5 mg/L.

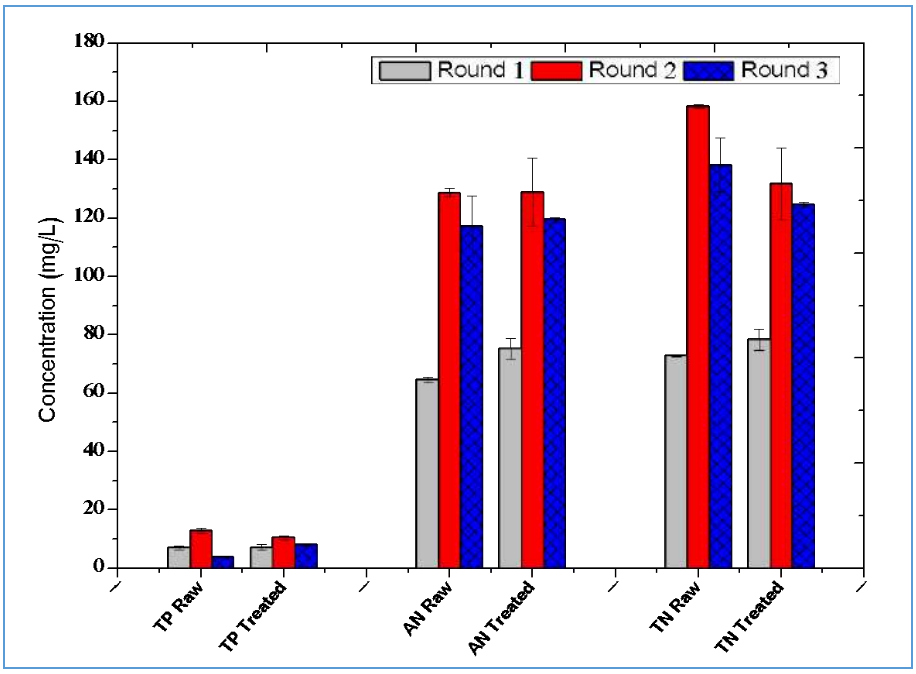

Figure 5-14: Nutrients concentrations in raw and treated composite water during different sampling campaign for 4S-002-N

The raw wastewater characteristics are in good agreement with Singh et al., 2009. It was also noticed that the AN and TN concentrations are slightly higher in the treated water than the raw wastewater during the 1st round, it may be due to sludge accumulation and improper functioning and maintenance of anaerobic filters and reed bed. It was noticed that during sampling campaign that the anaerobic filters were having scums and HFB are not having a uniform distribution of inflow over the entire width of the bed. Subsequently, there was not much increase in the performance of the system for nutrients removal, may be due to improper maintenance of horizontal flow bed filter. A similar trend was followed by Laber et al., 1999 and Bista et al., 2015, that the performance of HFB was affected by lesser plant species.

The faecal coliform level in the raw wastewater was in the range of 2.1x 10^8 to 2.4x10^9 as shown in Figure 5-14. The faecal coliform was found to be reduced to 4 - 5 log reduction (1.2 x 10^4 – 2.1 x 10^4). The reduction may be due to filtration process and natural decay of the microorganisms.

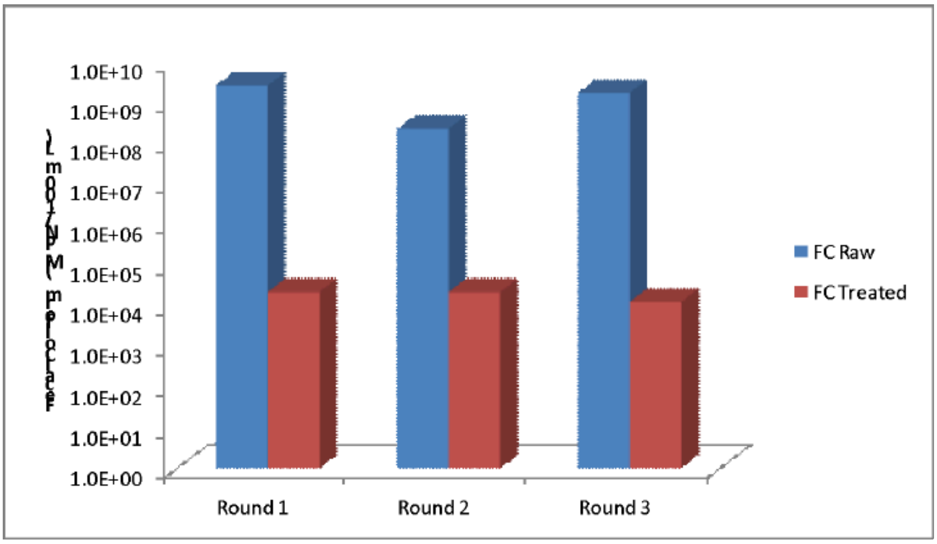

Figure 5-15: Faecal coliform concentration in raw and treated composite water during different sampling campaign for 4S-002-N

4.2.2.4 Results of the performance of 4S-004-N

a. Physical parameters during three round of sampling

There was the provision of separate grey water and black water sewer connected to separate integrated septic tank with ABR. Originally, the system waste designed to treat both grey and black water. However, after frequent over flooding of horizontal flow bed, the outflow from the integrated septic tank with ABR for grey water was pumped out and diverted from HFB. Thus, only samples from the black water were collected as influents throughout all round of samplings. The inflow in the systems depends upon the number of guest in the hotel and the flow depends upon uses of toilets. Thus, it was not possible to measure discharge each and every two hours as sampling procedure developed for this study. However, the black water pipe in the manhole to the system was blocked to collect sample every two hours. Once the sample was collected, the pipe was unblocked to drain all black water into the system. Similarly, the system consists of collection tank to collect effluent. The collected effluent from the tank was only pumped out after midnight to irrigate gardens. Thus it was not possible to measure discharge of outflow, however, the samples were collected from the collection time for every two hours to prepare a composite sample.

The anaerobic unit of the system gets desludged once every four years. Throughout the sampling round the system was not desludged. The filter media of horizontal flow bed at inlet section was clogged and flooding of HFB was common until the effluent from collection tank was pumped out. The reeds in the HFB were limited and healthy.

The average pH value of the raw wastewater was ranged from 6.8-8.9. The average minimum and maximum turbidities were 582 NTU and 849 NTU during a 1st and 3rd round of sampling respectively. Similarly, the average minimum and maximum electrical conductivity were 1459 μS/cm and 2080 μS/cm during a 3rd and 2nd round of the sampling. While the average pH value of the treated wastewater ranged from 6.8-7.7. The average minimum and maximum turbidities were 14 NTU and 29 NTU during a 1st and 2nd round of sampling. Similarly, the average minimum and maximum electrical conductivity were 712 μS/cm and 1771 μS/cm during the same round of sampling.

b. Concentration and Removal Efficiency of Various Parameters

The BOD concentrations in the raw wastewater were in the range of 725-1512 mg/L and the COD concentration was in the range of 1453-3000 mg/L. The suspended solids concentration in the raw wastewater was in the range of 1080-1945 mg/L as shown in Figure 5-16. The treated water has a BOD concentration of 74-107 mg/L, COD of 150-214 mg/L and TSS of 1.5-43 mg/L.

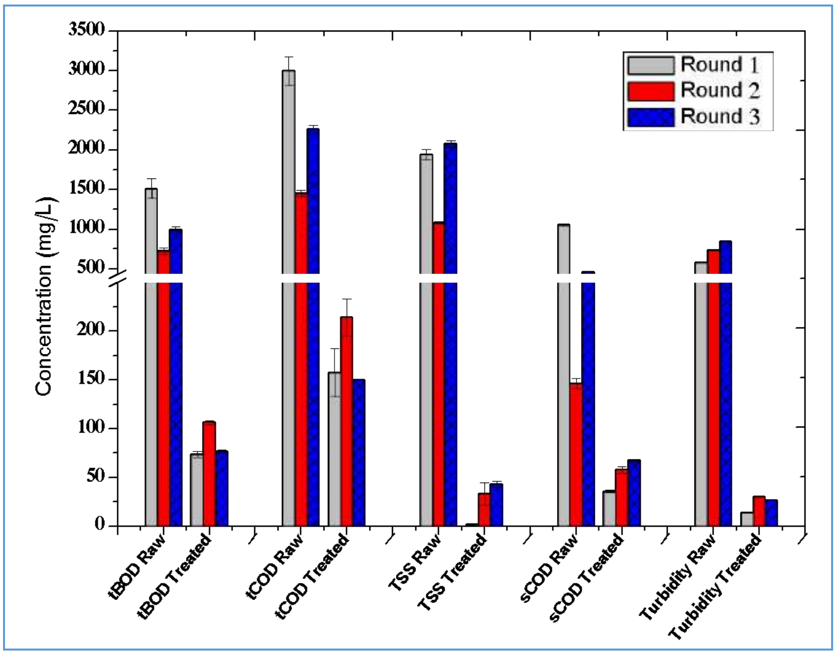

Figure 5-16: Organics and solids concentrations in raw and treated composite water during different sampling campaign for 4S-004-N

The raw wastewater concentrations are in good agreement with Rutkowski et al., 2007 and Zhang et al., 2015. The removal efficiency of the organics and solids were: 89.7-93% for BOD, 89.6-93% for COD and 97-99.8% for TSS. The major reason for the better performance for the organics and solids removal is due to proper operation and maintenance of the ABR and HFB, also it was seen that the plants were grown healthy in the filter beds.

The nutrients level in the raw wastewater was (Total nitrogen (TN) – 222-1366 mg/L; Ammoniacal nitrogen (AN) - 195-1346 mg/L and total phosphate (TP) was 26.4-42.7 mg/L) (Figure 5-17). The TN value in the treated water was in the range of 24-152 mg/L and TP value in the range of 3.1-12.7 mg/L. Similar to organics, the nutrients removal was also significantly higher with 89% removal of TN and 70-88% for TP.

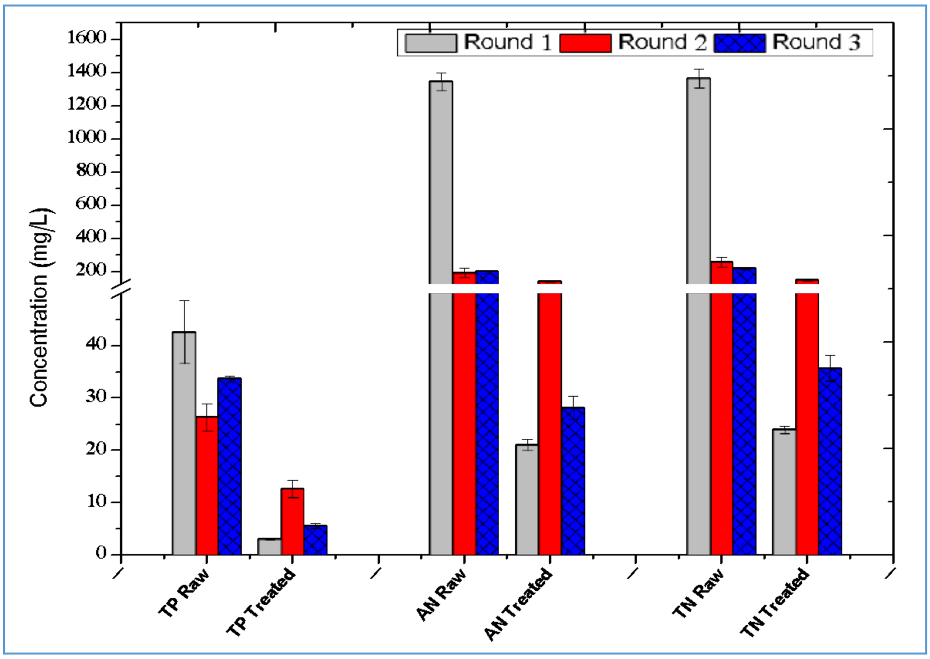

Figure 5-17: Nutrients concentration in raw and treated composite during different sampling campaign for 4S-004-N

The faecal coliform level in the raw wastewater was in the range of 1.1x10^7 to 1.1x10^8 as shown in Figure 7.3(c). The faecal coliform was found to be reduced to 1 to 4 log reduction with 2.1x10^4 to 4.6x10^6 MPN/100 mL in the treated water (Figure 5-18).

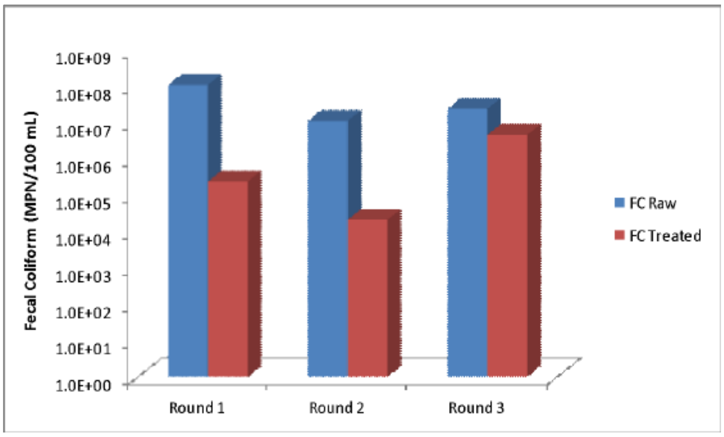

Figure 5-18: Faecal coliform concentrations in raw and treated composite water during different sampling campaign for 4S-004-N

4.2.2.5 Results of the performance of 4S-005-N

a. Physical condition and parameters during three Round of Sampling

The average inflow of raw wastewater during three round of sampling was 0.25 l/sec, 0.1l/sec and 0.17 l/sec and average outflow of treated wastewater in this periods were 0.23 l/sec, 0.04 l/sec and 0.13 l/sec. It was observed that during the 1st round of sampling vertical flow beds were ponded with stormwater runoff, in the 2nd round of sampling infiltration from cracked walls of VGB was observed and during the 3rd round of sampling cracks on the VFBs were repaired. The pH value of raw wastewater ranged from 7.29-7.96 and the average minimum and maximum turbidity were 57.6 NTU and 977 NTU during a 1st and 3rd round of sampling. While the average minimum and maximum electrical conductivity were 382 µS/cm and 977 µS/cm during the same round of sampling.

During 1st round of sampling, the accumulated sludge in the septic tank was normal and it was almost filled during the 2nd round of sampling while it has been emptied before 3rd round of sampling. The average pH of outflow from the septic tank was ranged 6.75-7.26. Also, the minimum and maximum turbidities were 43 NTU and 169 NTU during a 1st and 2nd round of sampling. Similarly, the minimum and maximum electrical conductivity were 420 µS/cm and 1162 µS/cm during the same round of sampling which was greater than that measured in raw wastewater.

During 1st round of sampling, there were numerous green reeds on the horizontal flow bed and entire inlet zone was clogged. Stagnant wastewater on the half width of the HFB was observed. In the 2nd round of sampling, reeds were trimmed and filter media from the upper layer of the clogged section was replaced. The pH values of outflow from HFB were ranged to 6.87-7.25 during three rounds of sampling. The minimum and maximum turbidities were 69 NTU and 102 NTU during a 3rd and 2nd round of sampling. Similarly, the minimum and maximum electrical conductivity were 466 µS/cm and 1124 µS/cm during a 1st and 2nd round of sampling.

The average pH of treated wastewater was ranged from 6.68-7.3 during three rounds of sampling. The average minimum and maximum turbidities were 5.2 NTU and 25.5 NTU during a 2nd and 3rd round of sampling. Similarly, the average minimum and maximum electrical conductivity were 433 µS/cm and 893 µS/cm during a 1st and 2nd round of sampling.

b. Concentration and Removal Efficiency of Various Parameters

The concentration of BOD was in the range of 250-550 mg/L and the COD concentration was in the range of 384-1150 mg/L. The suspended solids concentration in the raw wastewater was in the range of 164-562 mg/L as shown in Figure 5-19. The raw wastewater concentrations are in good agreement with Singh et al., 2009. The treated water has a BOD of 13.3-37 mg/L, COD of 28.3-75 mg/L and TSS of 5.0-32 mg/L (Figure 5-19). The overall removal efficiency was found to be: 93-95% for BOD, 92.6-93.4% for COD and 94-97% for TSS. It was seen from the graph that the performance of the treatment system was comparatively better during the second round of sampling than the other two rounds.

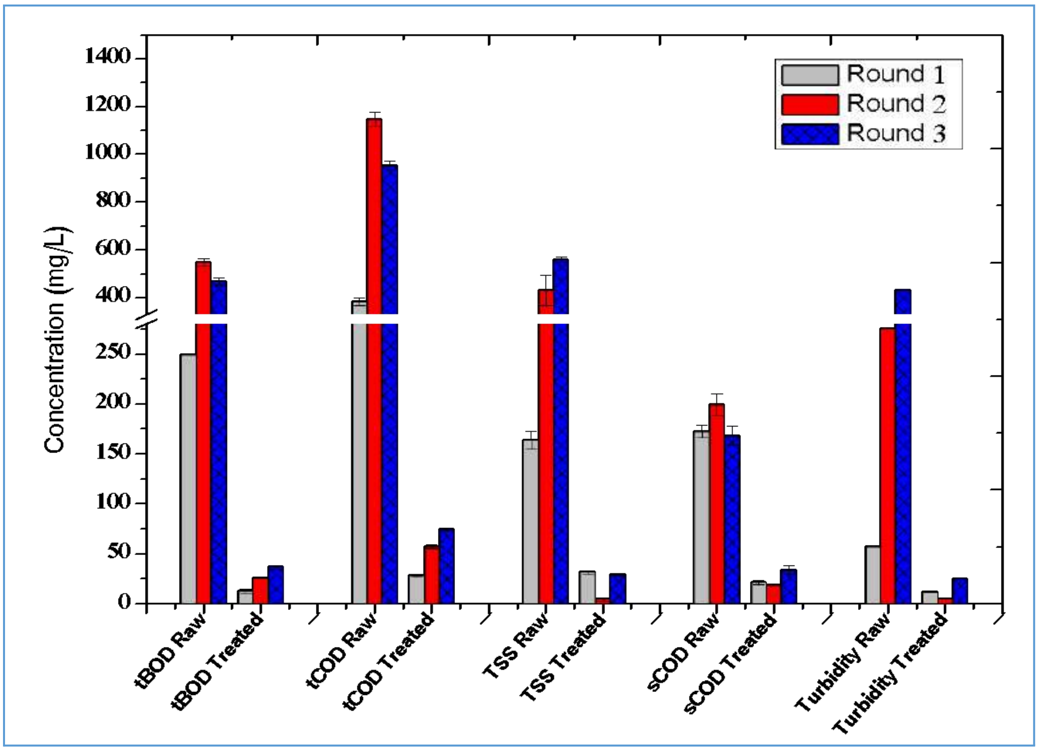

Figure 5-19: Organics and solids concentration in raw and treated composite water during different sampling campaign for 4S-005-N

The nutrients level in the raw wastewater was (TN – 45-150.6 mg/L; AN – 32-104.8 mg/L) and total phosphate (4.9-12.1 mg/L). The TN value in the treated water was in the range of 38-64 mg/L and TP value in the range of 2.2-7.1 mg/L (Figure 5-20). The removal efficiency of the nutrients was found to be; TN was in the range of 16-58% and TP was in the range of 41-55% for TP. The removal efficiency was not as high as organics and solids removal.

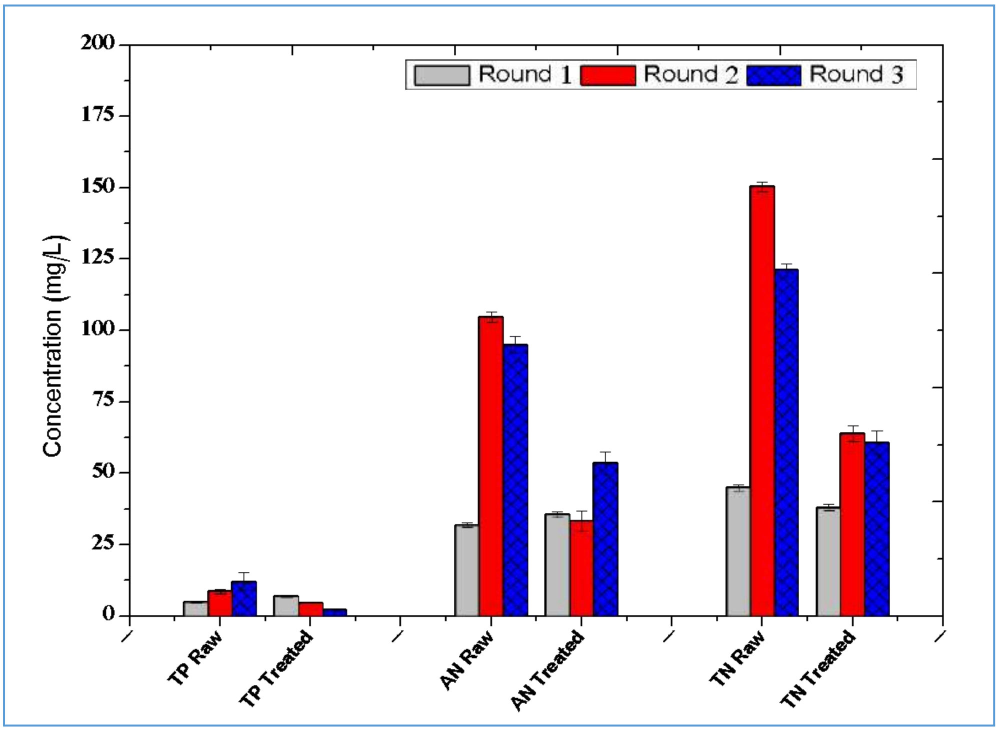

Figure 5-20: Nutrients concentration in raw and treated composite water during different sampling campaign for 4S-005-N

The faecal coliform level in the raw wastewater was in the range of 2.4x10^6 to 2.4x10^8 and was to 1.5x10^5 to 2.1x10^6 with 1 to 2 log reduction (Figure 5-21). The faecal coliforms are mostly removed by degradation, natural death and few by absorption.

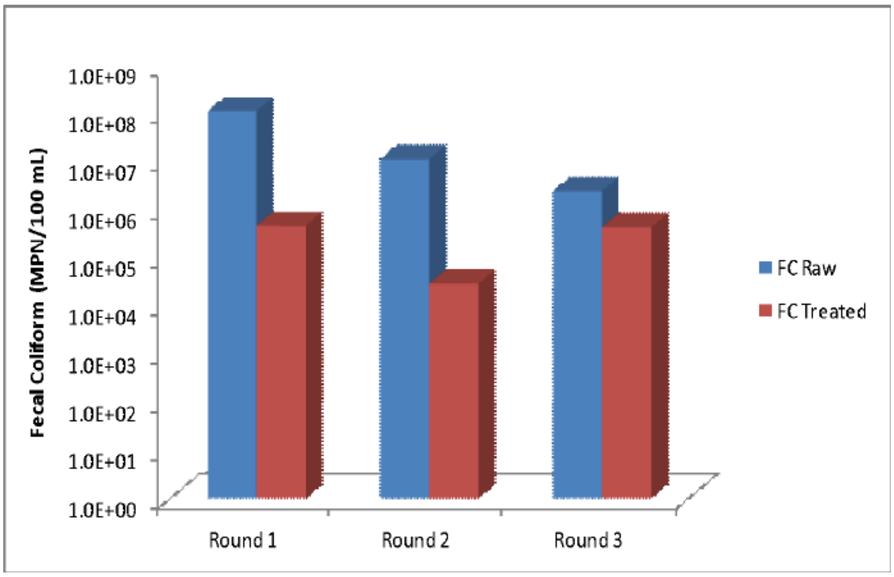

Figure 5-21: Faecal coliform concentration in raw and treated composite water during different sampling campaign for 4S-005-N

4.2.2.6 Results of the performance of 4S-009-N

a. Physical Condition and parameters during Three Rounds of Sampling

The system 4S-009-N is comparatively new among other assessed systems and also polishing pond was inbuilt in it. The average inflow of raw wastewater in the systems for three rounds of sampling were 0.34l/sec, 0.23 l/sec and 0.23 l/sec. Similarly, the average outflow of treated wastewater was 0.27 l/sec, 0.27 l/sec and 0.19 l/sec. The average pH value was in the range of 7.18 – 7.52. The average minimum and maximum turbidities were 140 NTU and 190 NTU during a 3rd and 1st round of sampling. The average minimum and maximum electrical conductivity were 1088 µS/cm and 1333 µS/cm during the same round of sampling.

The accumulated sludge in the integrated septic tank with ABR was high throughout all the sampling. The pH values were a range of 6.6- 7. The minimum and maximum turbidities were 106 NTU and 177 NTU during a 2nd and 3rd round of sampling. Similarly, the minimum and maximum electrical conductivity were 1037 µS/cm and 1310 µS/cm during a 3rd and 1st round of sampling. Filter media in the horizontal flow bed were clogged and reeds were not equally planted throughout the bed. Flooding of the HFB was observed when treated wastewater from the component was not pumped out from collection tank to vertical flow bed in all sampling rounds. The pH value ranged was 6.8-7 in three round of sampling. The minimum and maximum turbidity were 17 NTU and 44 NTU during 3rd and 1st round of sampling. Similarly, the minimum and maximum electrical conductivity were 862 µS/cm and 1215 µS/cm during the same round of sampling.

The vertical flow bed and polishing pond were in good conditions throughout the sampling. In the 1st round of sampling VFB consist of numerous green reeds and pond filled with water hyacinth. While during a 2nd and 3rd round of sampling reeds were trimmed. The pH value of outflow from VFB was ranged 7-7.3. The minimum and maximum turbidities were 3.42 NTU and 9.37 NTU during 3rd and 1st rounds of sampling. Similarly, the minimum and maximum electrical conductivity were 471 µS/cm and 866 µS/cm for the same rounds of sampling.

b. Concentration and Removal Efficiency of Various Parameters

The BOD concentrations were in the range of 195-355 mg/L and the COD concentration was in the range of 401-765 mg/L. The suspended solids concentration in the raw wastewater was in the range of 152-250 mg/L as shown in Figure 5-22. The raw wastewater concentrations are in good agreement with Singh et al., 2009. The treated water has a BOD of 7-10.8 mg/L, COD of 16.8-34.9 mg/L and TSS of 4.8-26 mg/L (Figure 5-22). The removal efficiencies for the organic pollutants are; 96-97% for BOD, 95.4-96% for COD and 90-97% for TSS. It was observed that the COD concentration during the 3rd round of sampling was slightly higher compared to other rounds, may be due to the accumulation of sludge. It was also seen that the suspended solids concentration was higher in the 2nd round, the major reason is that plant was not properly maintained as the plants in the HFB and

VFB are trimmed and cleaned during the sampling campaign as well as waterlogging was observed in the HFB.

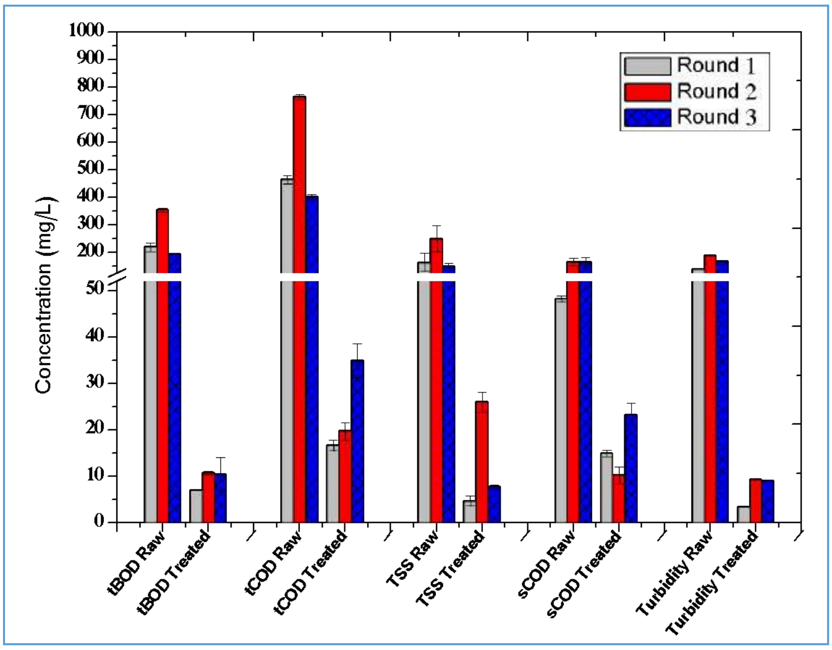

Figure 5-22: Organics and solids concentrations in the raw and treated composite water during different sampling campaign for 4S-009-N

The nutrients level in the raw wastewater were total nitrogen (TN) – 100-120 mg/L; ammonia nitrogen (AN) – 82-96 mg/L and total phosphate (TP) was 6.5-13.1 mg/L. The TN value in the treated water was in the range of 14.5-47.1 mg/L and TP value in the range of 0.3-3.5 mg/L (Figure 5-23). Similar to organics pollutant, the nutrients removal efficiency was also quite higher with, 61-86% for TN and 73-95.3% for TP. It was also observed that during the 2nd round of sampling the performance of the system was affected showing slightly higher concentration effluent for TN, AN and TP. The reason may be due to improper maintenance of the reed beds that is the absence of plants in the VFB and HFB was observed during sampling campaign, as well as the HFB was found to be waterlogged leading to poor performance.

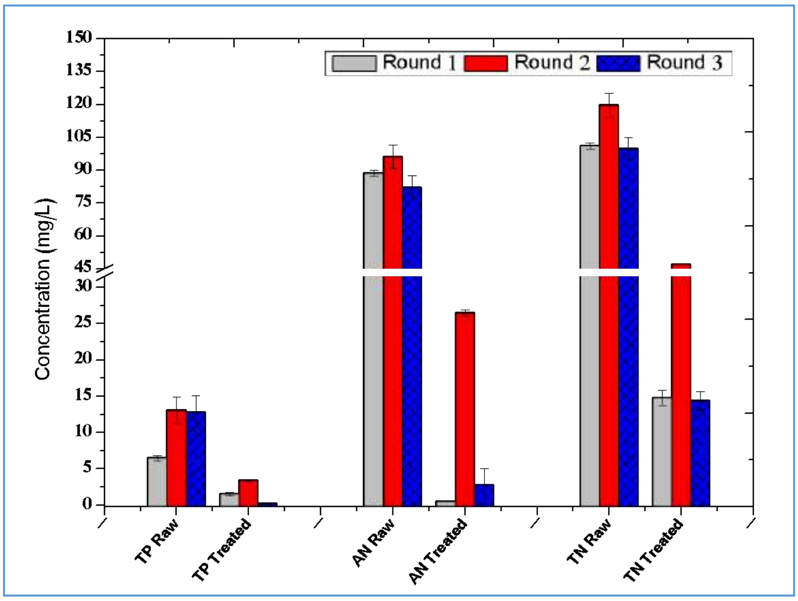

Figure 5-23: Nutrients concentrations in the raw and treated composite water during different sampling campaign for 4S-009-N

The faecal coliform level in the raw wastewater was in the range of 2.4x10^6 to 2.4x10^8 and was found to be reduced to 1 to 4 log reduction 2.4x10^6 to 9.3x10^6 (Figure 5-24). Similar to organics and nutrients the poor removal of FC was observed during the second round of sampling. The reason may be due to water overflowing in the HFB and absence of plants.

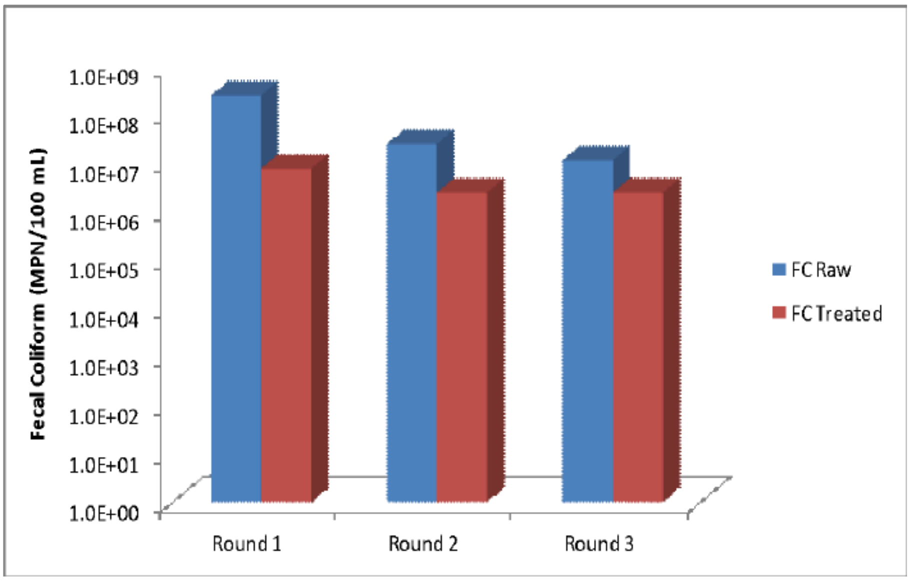

Figure 5-24: Faecal coliform concentration in the raw and treated composite water during different sampling campaign for 4S-009-N

4.3 Discussion and Conclusion

4.3.1 Discussion

The qualitative assessment of wastewater treatment efficiency of the systems shows that only 33.3% have good performance and wastewater loading was good in only 23.3% of the systems. The performance of the systems relies on the appropriateness of design and skill of O&M personnel with good motivation. Apart from this financial mechanism to sustain O&M, behaviour and satisfaction of users towards the system has a critical role for sustainable performance of the system.

The assessment of critical success factors for the design was good for 50% of the systems. Knowledge of population density, land availability, topography and reuse/safe disposal routes are preliminary information required for the design of the system. Apart from these, knowledge of wastewater collection systems in place or desired if the new system has to be built and characteristic of wastewater is essential. The good information on the potential to reuse, knowledge of existing wastewater collection system or desire system can be achieved only through the active participation of users during conception stage. However active participation of users was only observed in 6 (50%) of community/municipal systems during initiation phase and implementation phase. They were participated in community meetings and workshops to get information on proposed technology, its benefits and the probable contribution they should make. Thus it shows that user's expectation, opinion and cultural dynamics were less prioritized which eventually diminish ownership of the system by the users.

Most of the installations were built simple, low maintenance and natural biological treatment technology. These systems generally consist of anaerobic digestion units such as septic tank and the anaerobic baffled reactor (ABR) followed by constructed wetland where physical, chemical and biological treatment of wastewater occurs by means of filtration and nutrient uptake by reeds in its root zone. The anaerobic compartments function well only when the sludge is filled no more than $2/3^{rds}$ of its capacity (Kurniawan et al. 2016). Similarly, 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 the system required skilled personnel for basic O&M.

The qualitative assessment of the skill of O&M personnel showed that only 4.5% of caretakers from the systems have good skill. A majority of caretakers were without basic training on daily O&M and not able to identify the problem, solve and prevent it. Thus, significant scum layer and excess accumulated plastic waste were not observed in only 8 (26.6%) and 10 (33.3%) systems respectively. However, the motivation towards their job was good, the site was cleaned and equipment was properly arranged and available during their work hour. This indicates the possibility of enhancing the skill of O&M personnel and execution depends on skills of managing body.

The skill of managing body is an overall measure of knowledge on advantages and disadvantages, of the system, execution of duties and responsibilities and basic technical knowledge of the system. The CSF assessment on the skill of managing body shows 77.3% of the systems have to improve or insufficient management skill. The consequences were seen in the absence of planning, activities and monitoring guideline for supervision in O&M. The monitoring of the system was limited to visual observation of the effluent and abnormal water stagnant in a constructed wetland. The capacity buildup of caretakers through providing training were not placed in order and prompt delivery of repair and maintenance.

The secured financial sources have been seen as a major constraint for timely repair and maintenance of the system. Though the evaluation of cost recovery for O&M has scored well in 72.7% of the system, the collected service charges from users or additional investment from the owner of the system can manage expenses for basic O&M services. The service charges collected from users were insufficient to carry out irregular and major maintenance such as cleaning of clogged filter media, replacing worn out fittings and fixtures and upgrading of the system. Thus in the absence of enough budget and unwillingness of the owner to additional investment, the damaged components of the systems were neglected such that it ruins overall performance.

Besides these constraints, user's behaviour on following the instructions for the effective operation was not satisfactory. Only 18% of the systems has scored well on CSF assessment for their behaviour which included following the instruction for what to discharge and not, regular payment of service charges and reporting on the complaints. Lack of incentive among users may be most probably due to insufficient design consideration on active nutrient and energy recovery.

The consequences of these issues was observed in technical performance of the system. The lowest removal efficiency of 4S-002-N and 4S-020-N for BOD were 84% and 71% respectively with an average concentration of 59mg/l and 139 mg/l. The most probable causes for lower removal efficiency for BOD in 4S-020-N were higher accumulated sludge in the anaerobic unit (biogas digester) such that it was not removed since its operation in 2008 AD. Accumulated scum and sludge in the distribution channel of wastewater into constructed wetland was not regularly removed. The effect was a non-uniform distribution of wastewater in the wetland which favoured channelized flow ultimately reducing the efficiency. Moreover, inflow of runoff during rainy season and inundation of the constructed wetland during flood have clogged the filter media.

Similarly, in 4S-002-N which was constructed in 2009 and operated since 2010 have never emptied septic tanks and accumulated sludge in the tank was greater than $2/3^{rd}$ of the total volume. The system was equipped with an anaerobic filter (AF) which aids in additional degradation of organic matter and removes suspended solids before fed into a constructed wetland. However, the removal efficiency for BOD was only 84% with an average concentration of 59 mg/l. The probable reason for lower removal efficiency as compared to other systems was again non-uniform distribution of wastewater in the wetland due to unleveled and cracked distribution pipe network. Also, the level of swivel pipe was reduced, thus in totality, the only certain area was functioned and retention time period of wastewater in the wetland was reduced.

Beside this technical inefficiency, both the systems were managed by community-based organization membered by users. The right to infrastructure was owned by these CBO and land owned by the municipality. There was the provision of collecting service charges to recover basic O&M costs. The systems depend on a municipality for major repair and maintenance. Remarkably, caretakers from both these systems were untrained on basic O&M and require supervision and guidance from system managers.

Systems 4S-005-N, 4S-004-N and 4S-009-N were institutional level systems installed during 2001, 2011 and 2014 respectively. The average removal efficiency of BOD in these systems were 94%, 92% and 96% with an average concentration of 24.5 mg/l, 87 mg/l and 10 mg/l respectively. 4S-005-N consists of improved septic tanks, horizontal flow constructed wetland followed by two vertical flow constructed wetland in series. 4S-004-N was designed to treat grey water and black water through the separate integrated septic tank with ABR for both sources of wastewater and horizontal flow constructed wetland. Currently, the grey water was pumped out after treatment from integrated septic tank with ABR and ideally full treatment was carried only for black water. While 4S-009-N consists of integrated septic tank with ABR, horizontal flow constructed wetland followed by vertical flow constructed wetland. The system has polishing pond for additional aeration of treated wastewater before finally used for gardening and flushing of the toilet.

The result on the average concentration of BOD in these systems shows, the removal efficiency is improved with additional vertical flow constructed wetland. The unit improves quality of treated wastewater through additional aeration with intermittent feeding mechanism of wastewater into the vertical flow constructed wetland. Caretakers were mobilized from technical and maintenance unit. There was provision of regular desludging of the septic compartment, however, during the assessment higher accumulation of sludge was observed. Also, the stagnant wastewater on the horizontal flow constructed wetland was observed due to clogging of filter media. Thus it indicated that despite sufficient resources for operation and maintenance of the system, due to lack of operational guideline prompt O&M of the systems were not carried out.

4.3.2 Conclusion

The good performance of the systems depends upon many interlinked factors. Among those factors design consideration for active resource and energy recovery along with efficient wastewater treatment technologies has higher potential for creating incentive towards users and owners to invest for sustainable operation of the system. The enhanced skill of O&M personnel and managing body helps for developing and executing regular O&M and monitoring plan which increase removal efficiency of organic loads from raw wastewater.

5 References

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6 Annex

Annex 1:List of Small Scale Sanitation Systems Selected for Assessments

Name	Location	District	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6	Component 7
Namo Bhudha Resort	Namo Bhudha	Kavre	Settler	ABR	VFB				
Dhulikhel Hospital	Dhulikhel	Kavre	Settler	ABR	HFB	VFB	SDB		
Kathmandu University	Dhulikhel	Kavre	Settler	HFB	VFB				
Thakuri Gaun Sub System	Dhulikhel	Kavre	Bar Screen	FOG Trap	Grit Chamber	Settler	HFB	SDB	
Pipal Bot Sub System	Dhulikhel	Kavre	Bar Screen	FOG Trap	Grit Chamber	Settler	HFB	SDB	
Shrikhandapur Community Wastewater Treatment Plant	Dhulikhel	Kavre	Biogas Digester	HFB	SDB				
Nala Community Wastewater Treatment Plant	Nala	Kavre	Bar Screen	Settler	ABR	HFB			
Panauti Wastewater Treatment Plant	Panauti	Kavre	Bar Screen	FOG Trap	Grit Chamber	Settler	HFB	SDB	
Malpi International School	Panauti	Kavre	Settler	ABR	HFB	VFB	CT		
Chandeshowri Wastewater Treatment Plant	Banepa	Kavre	Bar Screen	FOG Trap	Grit Chamber	Settler	HFB	SDB	
Sunga Community Wastewater Treatment Plant	Madhyapur Thimi	Bhaktapur	Biogas Digester	HFB	VFB	CT	SDB		
Shusma Koirala Memorial Hospital	Shankhu	Kathmandu	Settler	HFB	VFB				

Gokarna Wastewater Treatment Plant (I)	Gokarna	Kathmandu	Grit Cham ber	Settler	HFB					
Gokarna Wastewater Treatment Plant (II)	Gokarana	Kathmandu	Settler	ABR	HFB					
Satya Sai Sikshya Sadan	Tokha	Kathmandu	Settler	FOG Trap	ABR	HFB	VFB	PP		
Dallu (Narendra)	Dallu	Kathmandu	Settler	ABR	VFB	CT				
Kritipur Community Housing	Kritipur	Kathmandu	Settler	HFB						
Nhyado Monastry	Pharping	Kathmandu	Settler	ABR	VFB					
Enpho	Baneshwor	Kathmandu	Settler	VFB	CT					
Kusunti Housing	Kusunti	Lalitpur								
Sano Khokana Wastewater Treatment Plant	Khokana	Lalitpur	Biogas Digest er	ABR	HFB	PP				
ICIMOD	Dhapakhel	Lalitpur	Settler	VFB	CT					
Ama Ghar	Godavari	Lalitpur	Biogas Digest er	FOG Trap	Settler	ABR	HFB	PP	SDB	
Park Village Water Front Resort	Pokhara	Kaski	Settler	ABR	HFB					
Hetauda Wastewater Treatment Kara Sub System	Hetauda	Makawanpur	Bar Screen	FOG Trap	Grit Chamber	Settler	HFB	SDB	soak pit	
Bharatpur Wastewater Treatment Plant (C1)	Bharatpur	Chitwan	Bar Screen	Grit Chamber	FOG Trap	Settler	ABR	HFB	SDB	
Lumbini Medical College And Teaching Hospital	Tansen	Palpa	Integr ated Settler with ABR	HFB	Collectio n Tank					

Sidhartha Children And Women Hospital	Butwal	Rupandehi	Septic Tank	ABR					
Chandra Ban Eco Resort	Buddhanilkantha	Kathmandu	Biogas Digester	ABR	AF	Collection tank			
Biratnagar Eye Hospital	Biratnagar	Morang	Integrated Settler with ABR	HFB					

Annex 2: List of Managers/Owners of Small Scale Sanitation Systems Interviewed

Name of System	Name of the interviewee	Designation of interviewee
Sunga Community Wastewater Treatment Plant	Krishnalal Goja Shrestha	President, Sunga Waste water Management Committe
Bharatpur Wastewater Treatment Plant (C1)	Birat Ghimire	Chief Officer, Environmental Section of Municipality
Park Village Water Front Resort	Santosh karki	General manager
Shusma Koirala Memorial Hospital	Bishwajeet Prajapati	Chief Administrator
Gokarna Wastewater Treatment Plant (I)	Prabhat Shrestha	Sr. Engineer, HCIBDC
Gokarna Wastewater Treatment Plant (II)	Radhya Krishna Shrestha	Chairman, dhyese wastewater user Committee
Satya Sai Sikshya Sadan	Dr. Narottam Prashad Upadhuay	Principal
Dallu (Narendra)	Naranedra Dangol	Owner
Kritipur Community Housing	Udayaman napit	Treasurer
Nhyado Monastry	Nima hemu	Assistant manager
ENPHO	Rajendra Shrestha	Outreach Director
Chandra Ban Eco Resort	Camilla	Owner
Namo Buddha Resort	Surendra Pandey	Manager
Dhulikhel Hospital	Gopal Shankar sainju	Chief Technical Officer
Kathmandu University	Rajendra Hada	Civil engineering, CED
Thakuri Gaun Sub System	Shree Bikaram banju	Community development officer
Pipal Bot Sub System	Shree Bikaram banju	Community development officer
Shrikhandapur Community Wastewater Treatment Plant	Purna Bahadur Karmacharya	Chairman, User's Committee
Nala Community Wastewater Treatment Plant	Yadav Krishna Shrestha	Treasurer
Panauti Wastewater Treatment Plant	Sudip thapa	Sub engineer
Malpi International School	Deepak Sharma	Administrative officer
Chandeshowri Wastewater Treatment Plant	Ram Sundar Bade	Engineer
Kusunti Housing	Renu thapa	Chairperson, working committee of housing

Sano Khokana Wastewater Treatment Plant	Gaynendra Maharjan	Chairman, Sanokhokana Wastewater treatment plant User's committee
ICIMOD	Narendra Brajacharya	Admin Associate, Maintenance Coordination
Amaghar	Tan Bahadur	House father
Hetauda Wastewater Treatment Kara Sub System	Krishna adhikari	Project manager
Biratnagar	Raju Upadhyaya	Maintenance engineer
Lumbini Medical College And Teaching Hospital	Laxman shrestha	Engineer
Sidhartha Children And Women Hospital	Gyandera	Financial Officer

Annex 3: Some Photographs of Sampling and Interview