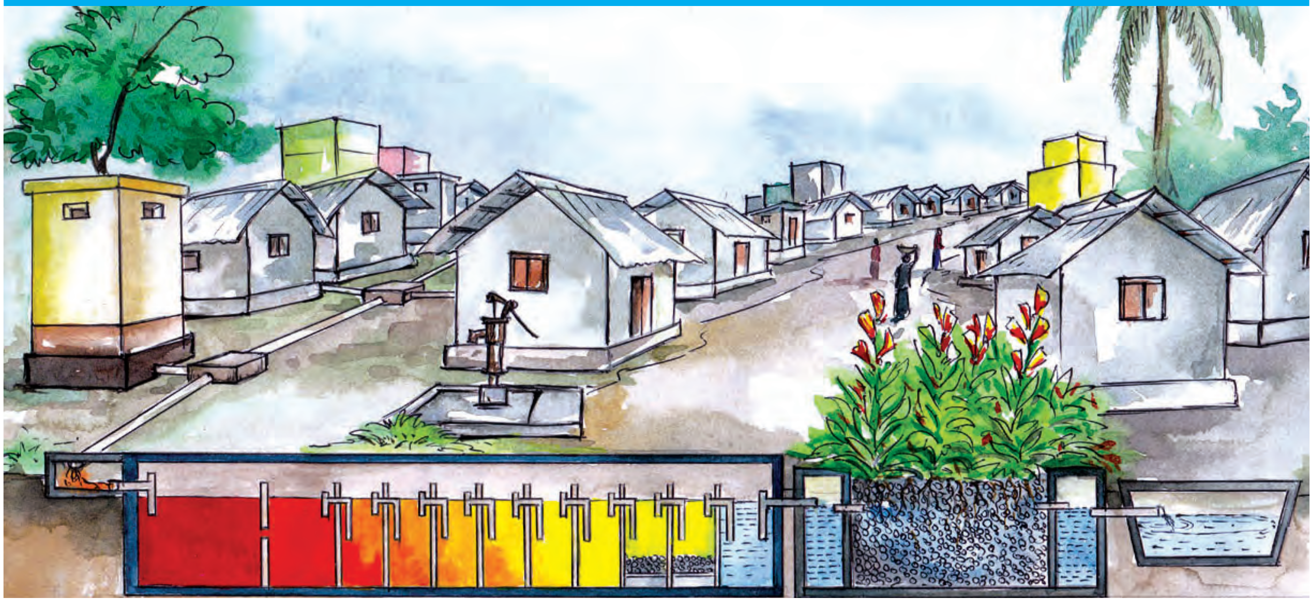
CASE STUDY

DEMONSTRATION OF TECHNOLOGIES | 2022 | SNV BANGLADESH



SNV

Decentralised wastewater treatment systems in Khulna: community-based and low-cost sanitation solutions

With the thrive on tackling the second-generation sanitation challenges in Bangladesh and therefore to demonstrate urgently needed alternative sustainable sanitation solutions for urban areas, SNV has been implementing since 2016 a pilot intervention to construct low-cost sanitation systems in Ward 10 of Khulna City Corporation.

Successful examples of innovative alternative sanitation solutions at scale are limited in Bangladesh and the region. Sewerage usually becomes an unviable option when urban planning is poor. Therefore, governments and donors generally promote conventional on-site solutions, like pit latrines or septic tanks. However, little to no attention is paid to the safe emptying, transporting, and treating of accumulated faecal sludge. In urban centres and areas that are rapidly urbanising, pit latrines and septic tanks are filling up. Urgent action is needed to test and introduce feasible and appropriate sanitation solutions.

Since 2016 SNV – with the technical assistance of WSUP – has been testing the feasibility and effectiveness of three low-cost sanitation systems that were introduced in Ward 10 of Khulna City Corporation (KCC). This case study presents SNV's experience implementing the project and the results of an evaluation of the systems three years after delivery.

Decentralised wastewater treatment systems

Decentralised wastewater treatment systems treat, reuse, or dispose of effluent in relatively close vicinity to its source of generation. These systems are implemented at the community level and usually consist of several components.

Project implementation

The project demonstrated various technical solutions and management models applicable for low-income areas; worked as a learning hub to disseminate success and improvement areas to other organisations and government. This project was built on the experience of WaterAid in Ward 11 in Khulna and WSUP in Dhaka with similar systems.

Feasibility study

A feasibility study in August 2016 kickstarted the project. The study, conducted by WSUP, assessed on-site Water, Sanitation, and Hygiene (WASH) facilities in Ward 10 and identified the institutional and socio-economic factors that impact the facilities. In addition, WSUP explored both the advantages and disadvantages of applying a Community-Based Systems (CBS) approach in the management of decentralised wastewater treatment systems. The study's findings[1] led to the following recommendations for the pilot project:

- increase investments in communal infrastructure for faecal sludge management;
- approach complete treatment and end-use through block-level solutions as opposed to cluster or city-wide solutions; and
- ensure that the infrastructure selected for the pilot project in Ward 10 is applicable for the entire Khulna city.

Implementation

In 2017, WSUP was hired to provide technical advice to construct the pilot interventions through a "community contracting system." A total of three sites, mostly with no containments, were selected for piloting in consultation with the user groups, KCC and SNV.

The availability of space guided the location of the implemented systems. Where possible, the systems were placed in the back alleys between homes whose width varied between 1.5 and 2 metres.

The settlers needed to be placed closest possible to the road to allow regular emptying as they fill up most frequently.

None of the implemented systems serves greywater. Only the blackwater line is connected. In all systems greywater is discharged to the open drain.

Technical components considered for decentralized wastewater treatment systems

Decentralised systems comprise different treatment steps and respective components and modules depending on local conditions. Implemented modules in the pilot are described below:

- Wastewater transport/network: Simplified Sewer (SS) network

[1] 'The high level of no containment, the lack of soakaways for many septic tanks, the poor hydrogeologic conditions that prevent the safe functioning of soakaways, and the limited space available in Ward 10 require investment in communal infrastructure for faecal sludge management.' Read the full study here.

[2] Gutterer, B. et al., 2009. Decentralised wastewater treatment systems (DEWATS) and sanitation in developing countries: a practical guide. Loughborough: WEDC, Loughborough University.

transports wastewater via gravity through shallow dug pipes. Design assumptions are less conservative than conventional sewer (smaller diameter pipes of 100-200mm, minimum depth of cover of 0.2m).

- Primary treatment/sedimentation
  Settler or septic tank (S) combines mechanical treatment through sedimentation and biological degradation of settled organic solids. Septic tanks are used for wastewater with a high percentage of settleable solids.
- Secondary treatment/anaerobic process:
  Anaerobic Baffled Reactor (ABR) (or baffled septic tank) is an underground, watertight tank with a series of chambers designed to function as multi-chamber septic tanks. The biological degradation is increased by forcing the wastewater through active sludge beneath chamber-separating baffles. ABRs are most appropriate for wastewater with a high percentage of non-settleable suspended solids and narrow COD/BOD[3] ratio.

  Anaerobic Filter (AF) (fixed-bed/film reactors) is an underground, watertight tank with a series of chambers filled with a fixed filter media that reduces TSS[4]. It provides surface area for bacteria to grow and further reduce BOD. AFs combine mechanical solids-removal with the digestion of dissolved organics. Pre-settled wastewater with a low percentage of TSS and narrow COD/BOD ratio passes through the active bacteria mass growing on the filter, resulting in an estimated 85-90% reduction in TSS and BOD.

[3] COD: Chemical Oxygen Demand
BOD: Biochemical Oxygen Demand

[4] TSS: Total suspended solids

- Tertiary treatment/aerobic
  Due to space constraints, no tertiary aerobic treatment (e.g., using constructed wetlands) and post-treatment (i.e., polishing ponds) could be implemented further to reduce pathogens, total nitrogen, and phosphorus. Therefore, the systems were not expected to reach BOD_5 levels complying with the ECR-1997 threshold of less than 40mg/l.

Details on implemented systems

All three implemented systems use the same treatment technology and comprise varying numbers of chambers for SS+S+ABR+AF.

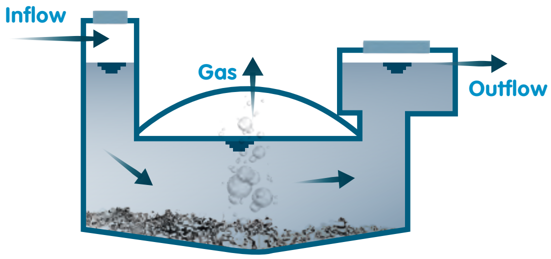
Only system 1 is designed as a low-cost system. The consecutive chambers (4S+4ABR+2AF) are constructed from prefabricated concrete rings. Those are considered cheaper as the production is local, faster and the units have thinner walls (50mm).

The AF chambers of all three systems contain bristle filters.

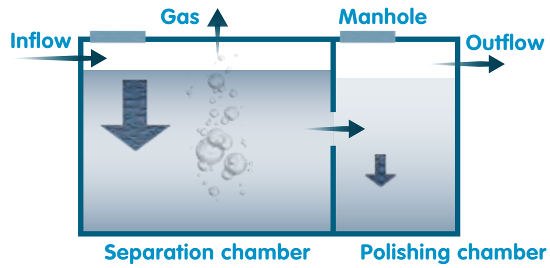
Photo 1: A decentralised wastewater treatment system in the middle of road 276 and 277 in ward 10 in Khulna

Typical decentralized wastewater treatment systems combine the following four technical treatment steps in a modular manner: (Source: DEWATS Handbook)

1. **Primary treatment / sedimentation / settler:** sedimentation ponds, septic tanks, fully mixed digesters (bio-digester), Imhoff tanks.

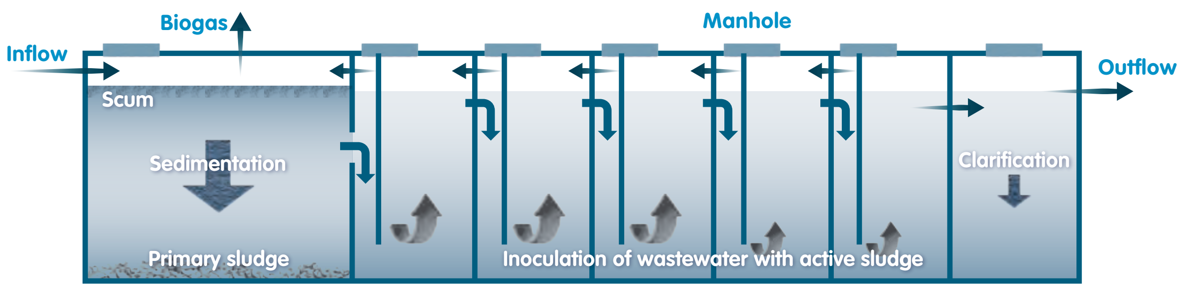


Bio-Digester

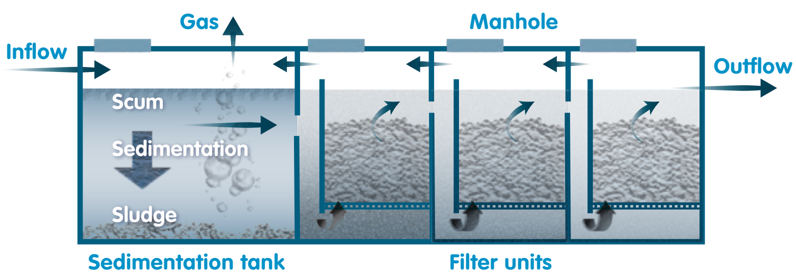


Septic tank

2. **Secondary treatment / anaerobic treatment:** anaerobic baffled reactors (baffled septic tanks), fixed bed filters (anaerobic filters or anaerobic and facultative pond systems).

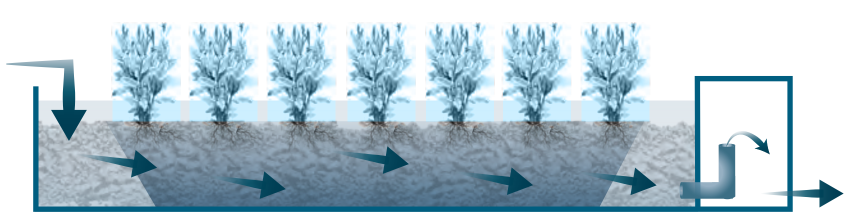


Anaerobic baffled reactor



Anaerobic filter

3. **Secondary and tertiary aerobic / facultative treatment:** constructed wetlands (subsurface flow filters)

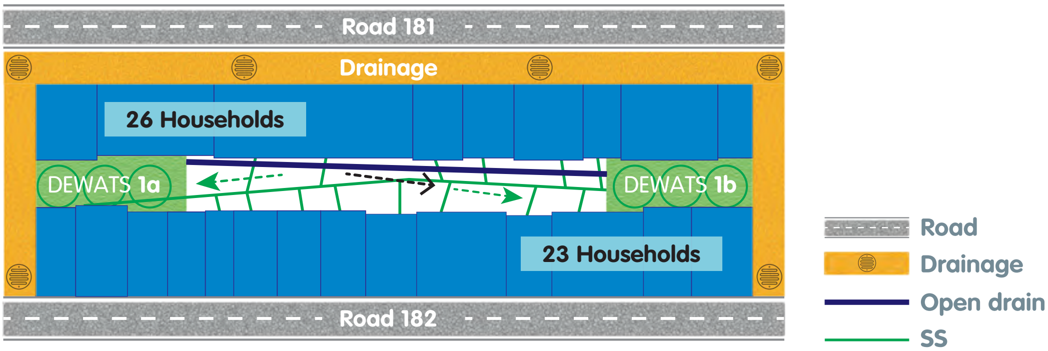


Horizontal gravel filter

4. **Post-treatment / secondary and tertiary aerobic / anaerobic treatment:** polishing ponds

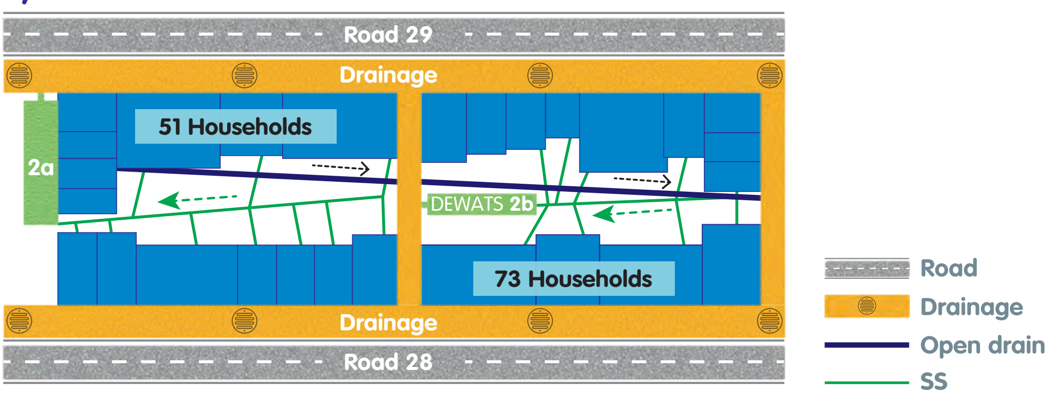
Systems details

System 1 (low cost)



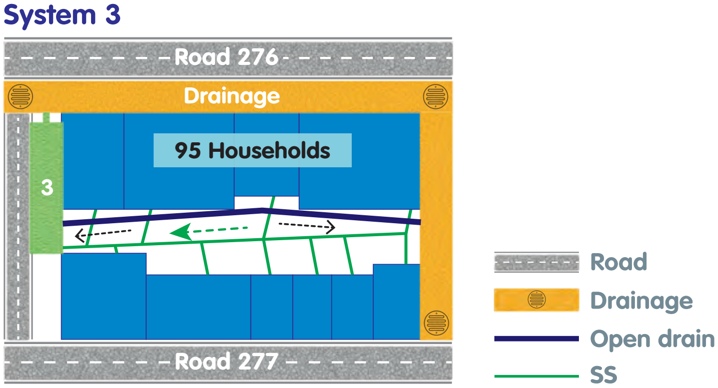
# Units	# People	Connected households*	Technical components	Cost (BDT)
2 Units 1a (east side) & 1b (west side)	199 People (107+92)	49 Households (26+23)	4S+4ABR+2AF (each unit)	6,05,879 (≈6,059 €)

System 2



# Units	# People	Connected households*	Technical components	Cost (BDT)
2 Units 2a (north side) & 2b (south side)	472 People (192+280)	124 Households (51+73)	2S+6ABR+3AF (each unit)	19,69,000 (≈19,690 €)

System 3



# Units	# People	Connected households*	Technical components	Cost (BDT)
1 Unit	318 People	95 Households	2S+6ABR+3AF	11,65,000 (≈11,650 €)

Performance assessment

To assess the performance of the decentralised wastewater treatment systems, every six months, effluent water quality tests were performed and once a sludge measurement. Moreover, one user survey was conducted to understand the practice and feedback.

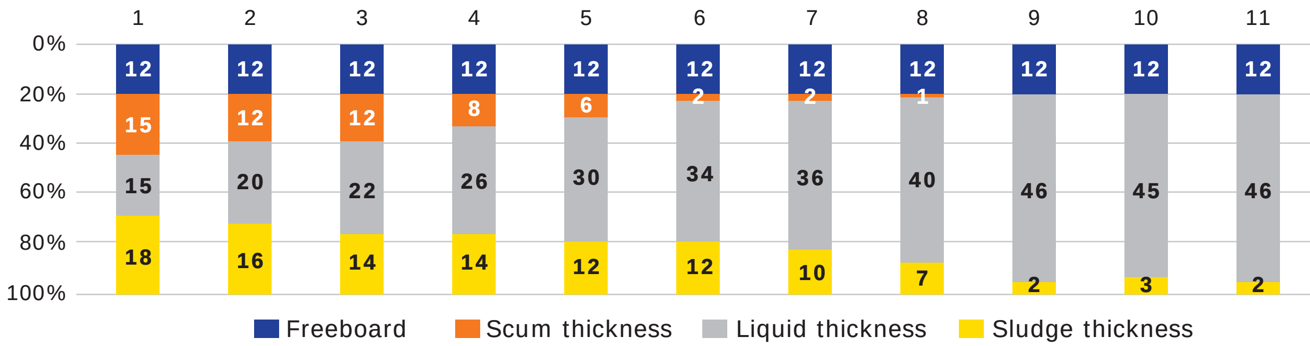
Effluent water quality tests

The effluent of the systems needs to comply with the national Environment Conservation Rules (ECR 1997, Schedule 9). For BOD_5 a threshold of 40mg/l, and for faecal coliform, 1,000/100ml applies. As seen in the table below, thresholds are mostly not met, which was expected as the tertiary and post-treatment steps are not implemented. However, for BOD_5 levels, a considerable reduction during treatments can be observed. Issues that might have hampered the performance of the wastewater treatment systems were identified during the sludge measurements discussed below.

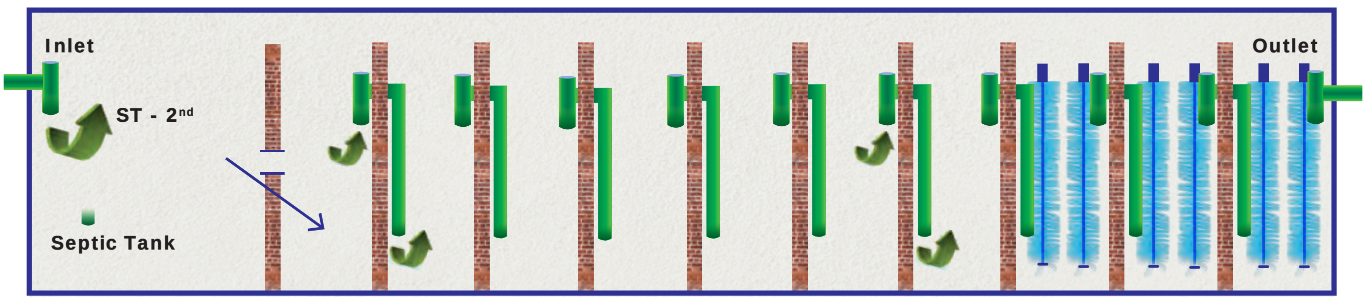
However, faecal coliform levels do not look reassuring. The results would suggest a problem in either sampling or analysing. Cross-checking of sampling methods and laboratory results are necessary even more so as inlet BOD_5 levels seem far too low for blackwater, which can indicate unauthorised greywater intrusion.

Date	System 1			System 2			System 3		
	Inlet	Outlet	Reduction / Growth Rate	Inlet	Outlet	Reduction / Growth Rate	Inlet	Outlet	Reduction / Growth Rate
BOD_5									
October 2018	264	246	-7%	168	156	-7%	150	156	+4%
July 2019	183	47	-74%	240	60	-75%	246	111	-55%
September 2019	300	84	-72%	372	156	-58%	354	66	-81%
January 2020	138	144	+4%	228	54	-76%	186	48	-74%
November 2020	210	186	-11%	312	258	-17%	174	162	-7%
March 2021	192	30	-84%	90	84	-7%	72	36	-50%
Faecal coliforms									
October 2018	1,080	900	-17%	780	660	-15%	780	1,140	+46%
July 2019	1,600	900	-44%	2,000	200	-90%	1,800	500	-72%
September 2019	300	4,000	+1,233%	500	2,400	+380%	500	300	-40%
January 2020	9,200	9,600	+4%	4,200	5,000	+19%	6,600	11,400	+73%
November 2020	5,200	8,000	+54%	3,200	4,600	+44%	2,200	4,600	+109%
March 2021	3,750	8,700	+132%	5,300	4,700	-11%	5,400	1,200	-78%

The test results from October 2018 suggest the systems were not operational.



System - 2(A) West Side



Section of pipe setting arrangement

Sludge measurements

After three years of operation, in July 2021, the scum and sludge volumes in each chamber of each unit of the wastewater treatment systems were measured. These measurements allowed conclusions on the performance of the systems and, even more importantly, disclosed shortcomings during the construction phase. In a well-functioning decentralised wastewater treatment system using S+ABR +AF, the sludge layer decreases by each chamber. Major sludge accumulation would happen in the settler.

System 2A's graph shows the measurements taken. This system did not show significant performance abnormalities or construction shortcomings. For the other systems, the following issues were identified:

- In system 1A and 1B there was a peak of sludge build-up at chambers 6 and 5, respectively. Each of the two households is connected directly to these chambers to avoid blockages.
- The settlers in system 1 were not constructed correctly.
- In system 2B and 3, the ABR section had no scum layer due to wrong pipe settings. Therefore, the scum moves to the next chamber. Instead of decreasing sludge layers, the sludge builds up till reaching the AF.
- The outlet of system 3 is submerged in the public drainage. Therefore, drain water/sludge/solids enters the AF and renders the filter material unfunctional.

The above-identified issues were corrected during the upgradation of the systems in 2021 (see *Upgradation*).

User satisfaction

The most common problems for a household connected to the decentralised wastewater treatment system are the backflow of water and blockage. Backflow of water can be avoided by raising the floor levels. The blockage is most often caused by individual misuse, like disposing cloth or similar material in the toilet. Since there were no individual inspection chambers, the abuse affected the whole community, leading to dissatisfaction. However, according to a survey conducted by SNV in November 2020, the users are generally satisfied with the system as it is a major improvement compared to the situation before.

Photo 2: System 1

Photo 3: System 3

Photo 4: Neighbouring alley

A positive side effect of the decentralised wastewater treatment systems is creating and beautifying open space.

Upgradation

Based on the performance assessment and respective learnings, the systems were upgraded with major activities below:

- Correct identified construction faults;
- Raise toilet floor levels, where necessary, to avoid backflow;
- Construct secondary chambers to prevent full-system failure by clogging in case of individual misuse;
- Repairing chambers and replacing broken slabs;
- Repairing drainage systems and adjusting the slopes where necessary;
- Connecting additional houses to drainage (greywater) and decentralised wastewater treatment (blackwater).

Initially, the upgradation aimed to connect greywater for its treatment. However, the space limitations did not allow extending the existing systems, and where space was available the community were uninterested.

Community participation

Users' participation comprises different aspects like the involvement of men and women in the different planning stages, operation and maintenance (O&M), community knowledge, and ownership.

Involvement of users

User involvement was guaranteed by including the communities in each planning and implementation step.

During the planning stage, an advisory committee for all systems and a purchase committee were formed during the construction phase. The advisory committee was tasked to find a sanitation solution for the ward. It was responsible for motivating people, jointly purchasing materials with WSUP, solving problems in the field, and selecting the management committee. 2-3 meetings were convened. After construction, the purchase committee dissolved, and the community management committee was formed.

Operation & Maintenance (O&M) community model

The task of the management committee was to collect money for the CAPEX and OPEX contribution and internal problem-solving. O&M plans including projected cost were agreed upon by the committee. However, the management committees are not functioning as planned. They don't meet or collect fees regularly even attend the systems only in the case of technical failure. None of the committees paid the agreed 5% of the CAPEX. One reason for this significant shortcoming was the election campaign promising free services during the implementation phase. However, in general, communities are willing to pay a fee.

Challenges during community participation

Four systems were envisioned initially. However, due to the high resistance from the local community with higher social status, one system was not built. The community members might have perceived the system as a pro-poor solution and, therefore, not applicable.

Generally, it is found that community approaches are more challenging to implement in higher-income areas.

Community knowledge and ownership

Community knowledge is to be developed and enhanced by the yearly operation and maintenance training convened by SNV. So far, the community seems to get the basic idea, though they still lack technical knowledge. They often consider the treatment systems as communal septic tanks. They are aware of regular desludging without scooping up the importance. Community knowledge is the lowest in system 3, where community participation was lacking from the start. Even though the most common problem is clogging, there is no understanding of why placing a net in the outlet. It is considered as an inconvenience for cleaning and extra cost. If broken or lost, it is mostly not replaced.

Stories behind the systems

"Look how beautiful this place is now. Clean and tidy. No problem to run a shop here. People can shop comfortably. It doesn't stink like before." This is how Rashid Mollah described the change with satisfaction, even though he is not a direct user of the system. Rashid runs a tiny grocery shop to earn his living opposite the decentralised system set up on Road 26-28.

Manju Monowara, a member of the maintenance committee of one of the systems, located at the alley in front of Babu Salam Mosque, believes that it significantly improved the sanitation system in her locality. "I am happy now with the toilet pan higher than before.", Manju said, adding a few concerns as well for further improvement: "From our experience, I

Photo 5: Manju Monowara, a beneficiary of the system

suggest considering several things before embarking on such activities elsewhere. An active committee where members meet frequently and eagerly can monitor the system to function better. Currently, they only go there and talk at their discretion when summoned before a visit by outsiders."

To keep the system clean, Monowara focuses on setting up nets at the front of each pipe, restricting the users from disposing of waste in their bathrooms, kitchens, and toilets into the system.

Shanta, a graduate girl, and her sister-in-law Rabeya Khatun, who lives at the beginning of the alley on 272 Road, also emphasised the mandatory net use at every household. They described, "We use nets in the mouths of all the water pipes in our home. However, a few of our neighbours don't. They throw almost everything through the tube into the system and thus clog. The irony is, they shout and complain that the system is not working correctly!"

Photo 6: A functioning system at the alley in Ward 10 in Khulna

Photo 7: Neighbouring people can now live in an odor-free, safe and healthier environment than ever before

Though many users, like Monowara, Shanta and Rabeya, are happy with the benefits, but not the all! Afroza Sultana Shabana, a working woman, and Abul Kalam Azad think the opposite as they suffer more than before. Often the water in their toilet comes inside instead of going out since the level of their toilet pans are below the pipes. Another unhappy user Qutbuddin Mallick opines revisioning the technical aspects before setting up such a system elsewhere.

Photo 8: Underground pipe-network system

To reap the full benefits from this system, Md. Ziaur Rahman, working as Assistant Conservancy Officer (Zone B) in KCC for the last few years, suggested, "it is imperative to maintain proper pipe sloping. Low pan of the toilets should be raised." Zia also emphasized law enforcement to keep the system functioning and incorporating the technology to prevent the odour. He added, "It is crucial to give the ward councillors a thorough orientation to succeed, from technology set up to maintenance, financial management, and its role in urban development." Moreover, users should get involved from the very beginning.

To avoid further complications, we need to involve family heads or decision-makers actively as the monetary issues are here. They also need to be told the limitations of this system.

Learnings and way forward

The intervention showed that decentralised wastewater treatment systems are an alternative and/or a complementary measure to sewerage networks for urban areas. The specific technology and materials used are flexible and need to be adapted to local conditions. The trialled low-cost option using prefabricated concrete rings proved unsuccessful. The material was not durable, construction was not necessarily faster, and the design did not facilitate more effective treatment. Ongoing and approved future constructions are therefore not following this design option.

The design of systems 2 and 3 can still be optimised. A stringent monitoring scheme performing sludge measurements in all chambers will facilitate the adjustment of dimensions and therefore the development of the most efficient technology design taking local conditions into account.

Photo 9: Community participation and, therefore, operation and maintenance is one of the major challenges

The major challenge is proved to be community participation and, therefore, operation and maintenance. Based on this experience, designing any future intervention as a PPP model is strongly recommended. The involvement of the private sector will guarantee reliable fee collection and professional operation and maintenance services and, by this, the unfailing functionality of decentralised wastewater systems.

Particularly for cities with already existing or planned sewerage networks, the synergies between centralised and decentralised systems should be exploited more.

Photo 10: Sub-inspection pit (8a) and main inspection pit (8b) of the sludge collection network

An additional gain of decentralised wastewater treatment systems, not discussed in detail in this paper, is the mitigation of climate change greenhouse gas (GHG) emissions compared to on-site sanitation systems (septic tanks and pit latrines) and the option to combine them with energy production, e.g. biodigestor with methane capture.

Centralising the Decentralised

A one-for-all technical solution is not possible in high-dense cities. Complementation and integration are probably the best ways to move forward. In Khulna, the water authority (KWASA) is initiating the construction of a conventional sewer network, which aims to cover more than half of the city. Access to the network is restricted by road width - wider than 3m – which covers only 65% of Khulna's roads.

Based on the above-described challenges of decentralised systems (no tertiary treatment due to space constraints, non-functionality of community-based committees) and looking into its advantages (simplified networks, adaptation to limited spaces, cheaper investment, and maintenance), it is proposed to connect ABR's outlets to sewer's trunk lines. This would have three gains:

1. The added wastewater is mainly water (no solids), which will improve the sewer network performance and reduce operational costs, particularly in a highly flat city such as Khulna, and a sewerage network that will require eight pumping stations.
2. KWASA will increase its sewer coverage by welcoming the decentralised systems as new customers. At the same time, it will increase the revenue, including the sanitation tariff into the current water bill.
3. As new customers, KWASA can centralise O&M and therefore provide more professionalised services to the decentralised systems, avoiding the challenges of community-based committees.

Our hope as SNV is that the proposed approach will be taken up and further developed and, thus, widens the available range of alternative technologies to ensure access to sanitation for all.

SNV

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About SNV in Bangladesh

SNV started working in Bangladesh in 2006. We design impact-oriented and scalable projects to help turn poverty into prosperity. Our work in Bangladesh contributes to improvements in urban sanitation, food safety in the horticulture sector, the promotion of gender equity, and the elimination of gender-based violence for workers in the garment industry. We focus on private sector engagement, institutional development, and local ownership of programmes.

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