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Evaluation of sanitation and wastewater treatment technologies: case studies from India

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ABSTRACT

This paper reports about the results of an evaluation of selected sanitation systems in India. The following sanitation systems were evaluated: septic tanks, communal Ecosan systems, biogas toilets, solid immobilized biofilters, multiple stage filtration and decentralized wastewater treatment systems (DEWATS). The evaluation has been based on an initial assessment looking at whether the systems comply with their intended benefits, and more in depth evaluations on cultural, economic and/or hygienic aspects where the initial assessment has not provided sufficient knowledge. The evaluation showed that all sanitation systems were well accepted by the users. The highest hygienic risk is present in septic tanks, where sludge handling poses a high risk for persons handling it.

Key words | biogas, DEWATS, ecosan, MSF (multiple stage filtration), septic tank, SIBF (solid immobilized biofilter)

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INTRODUCTION

It is well known that worldwide there is a large gap in developing countries with respect to the provision of adequate water supply and sanitation facilities and services. Despite major efforts only little progress has been achieved, varying between countries. Recent surveys (WHO-UNICEF 2008) have shown that in 2008 worldwide around 1.1 billion (10^9) people were still practising open defecation. In particular in South Asia open defecation is prevailing. Two out of every three Indians defecate in the open, which means 665 million people lack improved sanitation (WHO-UNICEF 2008). India is thereby the country with the highest number of people who practise open defecation.

Traditional latrines, which are widespread in the country, are the first step to manage excreta. The next step in the sanitation ladder is any form of improved latrines that ensure more hygienic separation of excreta and the final step is a flush latrine connected to a septic tank or a sewer network. Each successive step of the ladder represents a higher unit cost but is assumed to give a correspondingly lower level of health risk (Morella *et al.* 2008). In the current study different sanitation levels, from septic tanks to decentralized treatment chains including anaerobic as well as aerobic treatment of wastewater, have been studied.

The Indian National Urban Sanitation Policy (NUSP) was published in 2008 (Government of India 2008) and envisages that by implementing state sanitation strategies and city sanitation plans all Indian cities and towns will become totally sanitized to ensure good health of all citizens. There is special emphasis on hygienic and affordable solutions for urban sanitation. Technologies that promote the recycling and reuse of treated wastewater should be encouraged, and the recycling and reuse of treated

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wastewater for non-potable applications wherever possible should be encouraged. The NUSP already recognized the need to consider various factors when implementing a new sanitation system as often people are not ready or willing to adopt these and pay for service provision. Currently, the main focus is on construction, and operation and maintenance (O&M) has low priority (Nivedita 2010). The technologies are linked to a whole set of environmental, behavioural and cultural parameters that need be taken into account. A holistic approach is required for technology choice. Therefore, certain criteria and indicators have to be applied. Some studies have already dealt with the definition of a core set of indicators that are applicable for different sanitation and wastewater treatment technologies (Singh *et al.* 2009; Jones & Silva 2009).

Over recent years, several wastewater treatment technologies such as anaerobic baffled reactors (ABR) (Singh *et al.* 2009; D'Souza *et al.* 2009), constructed wetlands (Juwarkar *et al.* 1995), multiple step filtration systems (UNICEF 2007) or constructed soil filters (Kadam *et al.* 2008) have been implemented in India. This paper presents the evaluation of decentralized technologies and on-site options across India representing different steps of the sanitation ladder from septic tanks, as the simplest technology, to advanced decentralized treatment systems. A pragmatic approach was used to assess the technologies. Rather than setting up an evaluation framework comprised of a number of criteria and indicators which is then applied uniformly across all case studies, the indicators and criteria used for the evaluation were defined in a bottom up way for each selected technology, following the methodology described below. Reasons for success as well as factors for failure were analysed and crucial aspects for the successful implementation of sanitation and wastewater treatment technologies were identified.

METHODOLOGY

First, an initial assessment was conducted. The initial assessment evaluated the performance of the technology and the possibility of reuse of by-products. Appropriate indicators were chosen in order to assess whether the technology meets its intended benefits. For case studies which have not met their intended benefits or for which (non-acceptable) risks have been identified, more detailed investigation was conducted, such as e.g. additional hygienic or socio-cultural studies. All investigations were conducted in 2008–2009. Table 1 gives an overview of the evaluation process.

Socio-cultural evaluation

The conceptual model of Receptivity (Jeffrey & Seaton 2004; Roma & Jeffrey 2008) was developed to investigate the implementation and acceptance of water and sanitation technologies. Receptivity is defined as 'the willingness (or disposition) but also the ability (or capability) in different constituencies to absorb, accept and utilize innovation options' (Jeffrey & Seaton 2004).

The Receptivity agenda guided the formulation of survey questionnaires as well as the data analysis. The surveys were conducted by project partners, translators and interviewers. The surveys were administered verbally in face-to-face interviews with respondents. Question formats and coding were refined following a discussion with the project partners in the selected areas.

Table 1 | Evaluation criteria

Evaluation criteria	Indicator/assessment	Source
Social acceptance/ receptivity	Questionnaires to measure receptivity and explore socio-cultural aspects	Face-to-face interviews
Costs	Construction costs, operation and maintenance costs, affordability	Costs of previously constructed schemes, information from users
Hygienic risks	Qualitative hygienic risk assessment	Qualitative expert judgement, verification monitoring
Environmental considerations	Possibility to reuse by-products and quality of by-products	Qualitative expert judgement, verification monitoring

The assessment of the socio-cultural impact and risks had the following objectives:

1. Measure respondents' receptivity of the case study technologies, and the main socio-cultural reasons behind their attitude.
2. Explore the key socio-cultural issues and aspects that might enhance the recipients' awareness and acceptance of water and sanitation indigenous and exogenous technologies.

Socio-economic evaluation

In the socio-economic assessment users were asked about the costs of their current service level, their level of satisfaction, expectations for the future and their willingness to pay for improvements, as socio-economic aspects are one of the main factors influencing the decision to adopt a sanitation system (Martin & Pansegrouw 2009; Katukiza *et al.* 2010; Bolaane & Ikgopoleng 2011). A group of key questions was identified with supplementary questions confirming the results. Thirteen users of septic tanks and nine users of biogas toilets were interviewed.

Hygienic assessment

The approach taken essentially follows the initial steps or the system assessment approach within the WHO Guidelines for Wastewater, Greywater and Excreta (2006). A main difference is however that numerical values are not assigned, and thereby neither is a value for the 'probability of infection'. A reason for this is that the case study areas have not been followed on a regular basis but mainly visited during spot-check periods. Further, the analytical samples taken cannot be considered as a base for the validation of the different treatment barriers in the respective systems. For this a series of samples needs to be taken. The samples therefore instead represent 'verification monitoring' indicating if severe deviations are anticipated. Instead a summary of guiding factors have been given in relation to the different case examples and systems indicating potential factors that may govern 'risk variability' within the systems and some points that can function as guidance in 'risk mitigation' for the future.

In the screening assessment approach the human exposure through different transmission routes is a central component together with the identification of different technology or system components. The hygienic assessment built upon experiences in previous work such as Schönning *et al.* (2007) or Stenström *et al.* (2006).

DESCRIPTION OF SANITATION SYSTEMS

Different types of sanitation systems and decentralized wastewater treatment plants have been studied: septic tanks, communal Ecosan systems (urine diversion dry toilet [UDDT]), biogas toilets, solid immobilized biofilters, multiple stage filtration (MSF) and decentralized wastewater treatment systems (DEWATS). Table 2 shows the different technologies and their location.

Septic tank

The septic tanks were constructed in 2003/04. This technology is widespread in states like Uttarpradesh and Bihar. The systems have a standard design and are constructed by local masons. The black water is collected in the septic tank, which is connected to the storm water drainage, as can be seen in Figure 1. The sludge, which settles in the bottom, is removed once per year.

Ecosan (urine diversion dry toilet)

The communal Ecosan toilet in Asalthpur was constructed by the local non-governmental organization (NGO)

Table 2 | Overview of studied sanitation systems

Type	
Septic tank	Individual
Ecosan (UDDT)	Communal
Biogas toilets	Individual
Solid immobilized biofilter (SIBF)	Communal
Multiple stage filtration (MSF)	Communal
DEWATS	Communal

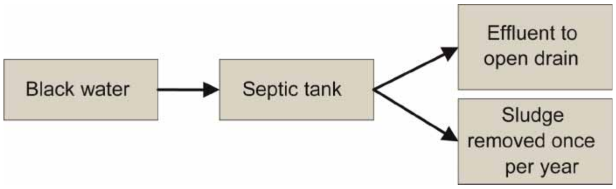

Figure 1 | Outline flow chart of the septic tank system.

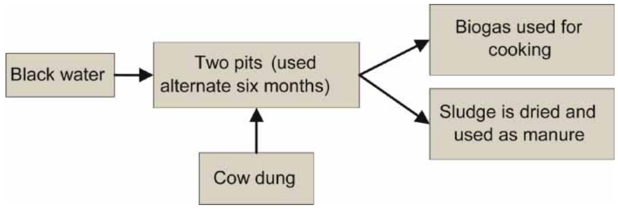

Figure 3 | Outline flow chart of the biogas toilet system.

FODRA in 2005. It should help the villagers to save the cost of chemical fertilizers by using manure produced by the Ecosan toilets and also serve as a more hygienic option for the villagers compared to open defecation which the majority practised before. As shown in Figure 2, the communally used Ecosan model in Asalthpur consists of two separate pits for the faeces and a separate urine collection chamber. After one pit is full the contents desiccate for six months whilst the other pit is used. After defecation the user applies one hand full of ash on the excreta. Urine is stored in the urine collection chamber, from where it is collected and used, directly without any processing, as fertilizer.

Biogas toilets

In both case study sites, Mahalunge and Nivale, the first biogas plants were introduced in the mid 1980s with the main objective to use cattle dung for the production of biogas. The motivation to connect the biogas plant to the toilets came from the Government of Maharashtra's Clean Village Competition. The households converted the existing biogas plants in two pit toilets and constructed additional biogas toilets. As shown in Figure 3, the system consists of household toilets with offset twin pits outside. Construction material could partly be found (bricks) or produced

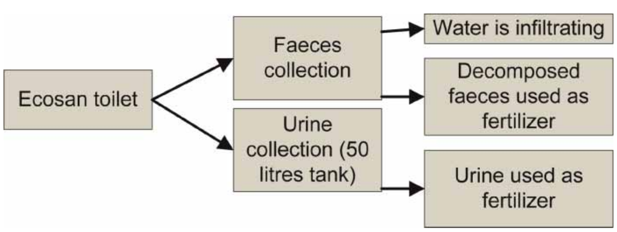

Figure 2 | Outline flow chart of the UDDT system.

(concrete ring, pan) locally. As it is a wet toilet system, faeces are flushed away with water. There is an additional inlet where the cow dung is mixed with water. This cow dung slurry is transported to the pit through clay pipes.

In the pit, flushed away faeces are left for decomposition. During decomposition the released methane gas is captured and the outlet is directly connected to the kitchen for use. The slurry of the pit is used as manure when dry.

Solid immobilized biofilter (SIBF)

The SIBFs were constructed in schools in 2004. Bharati and Kimmins are located within a tourist area and the Maharashtra Pollution Control Board (MPCB) made it mandatory for schools, hotels and other institutions to dispose of their waste in a proper manner. The MPCB checks once per year whether this has been achieved. As shown in Figure 4, the wastewater from the septic tank is collected in the collection tank. From the collection tank, the wastewater is pumped to biofilters 1 & 2 through pumps. After passing through biofilter 2, alum is added and the solid material settled. From the settling tank the water is pumped to a pressure sand filter and an activated carbon filter. The final treated water from the activated carbon filter is then chlorinated and stored in the treated water tank. This treated water is then reused for gardening/irrigation/toilet flushing.

Multiple stage filtration (MSF)

This system was implemented in 2002 in Kikwari, which is a village of 1,750 inhabitants. Due to low precipitation, it is difficult to conduct agricultural activities. Therefore, a treatment plant has been constructed with the aim to reuse the effluent for irrigation. As can be seen in Figure 5, the

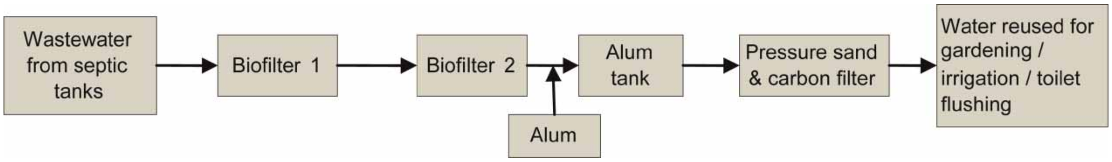

Figure 4 | Outline flow chart of the SIBF system.

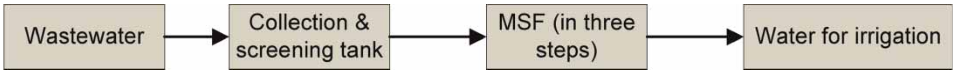

Figure 5 | Outline flow chart of the MSF system.

wastewater is first screened and stored in a tank for about one day so the larger solid particles settle down in the tank. Then the water is passed to a filter tank, where it is filtered in three stages (using different types of sands and bricks). After that, the treated water is collected in another tank, from where it is supplied to a fruit farm in the form of drip irrigation.

Decentralized wastewater treatment system (DEWATS)

This case study comprises a wastewater treatment plant that is treating the wastewater of a settlement of 650 people. It was constructed by the Hunnar Shaala Foundation in 2004. The water is used for irrigation of the surrounding green belts. As shown in Figure 6, the system consists of a primary treatment system with a settling and floating tank, a secondary treatment system of an up-flow type ABR, a tertiary treatment in subsurface horizontal flow (SSF) sand filters with reed beds, and, finally, a polishing pond for oxygenation.

The five evaluated technologies represent different levels of sanitation services. Whereas the septic tank aims only to provide better hygienic conditions, the Ecosan and biogas systems provide additional benefits (reuse of nutrients, biogas). The decentralized systems aim to reuse the treated wastewater for irrigation. Table 3 shows the intended benefits for the case study systems.

RESULTS

Septic tank

Result of initial assessment

The evaluation of the technology has shown that it was partly a failure case: the system is malfunctioning, but accepted as no other option is available. Initially the family members used to practise open defecation, now this has stopped and they use their own household level toilet. Users are satisfied with the system, but the disposal of the wastewater/sludge poses a health risk to the users as the emptying has to be done manually near the road. Additionally it poses a health risk to the overall community and especially the children that will come into contact with the effluent water.

Reasons for failure

The drawback of this technology is that the accumulated sludge in the tank has to be emptied manually and is discharged to the road which results in severe hygienic risks. The system itself is well accepted and the family members, who used to practise open defecation in the nearby railway track before, have now stopped this practice and use their own household level toilet. The new system is also safer in

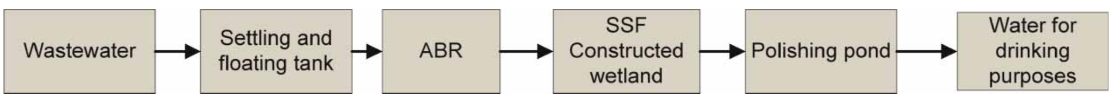

Figure 6 | Outline flow chart of the DEWATS system.

Table 3 | Intended benefit of the different evaluated systems. NA = Not applicable

	Basic sanitation			Wastewater treatment		
Intended benefit	Septic tank	Ecosan	Biogas toilets	SIBF	MSF	DEWATS
Better hygienic conditions	X	X	X	X	X	X
Reuse of nutrients, biogas	NA	X	X	NA[a]	NA[a]	NA[a]
Reuse of treated wastewater for irrigation	NA	NA	NA	X	X	X

[a]Treated water used for irrigation.

terms of violence against women as they do not have to leave their house during the night-time anymore.

Hygienic assessment

The system results in a high exposure for the persons emptying it accompanied with a high risk. Around 80% of the villagers suffer from waterborne diseases such as stomach and skin problems. The system further enhances the exposure, especially of children, from the open drainage ditches. It further enhances the risk of mosquito breeding and thereby of filariasis. The nearby collection pond, in which the effluent discharges shows total coliform counts of 1,512/100 ml and faecal coliforms of 118/100 ml. Microbiological contamination could also be detected in the water from hand pumps, which indicated that the groundwater has also become contaminated. However whether this was due to the effluents from the septic tanks or had come from other sources is presently unclear. The system needs immediate attention.

Socio-economic assessment

Septic tanks had construction costs of Indian Rupees (INR) 18,000 per unit and the time for construction was 15 working days. Some users stated that they think that the costs are high; the remaining interviewed users thought that it was not so expensive to construct these schemes. All respondents said the costs were affordable or even easily affordable. All users of septic tanks think that they will stay with their current service in the future. However, due to the waterborne diseases a family loses 25–30 working days per annum (both male and female) that results in a loss in income of INR 3,000 for males and INR 500 to INR 1,000 for females.

Ecosan

Result of initial assessment

The evaluation of the technology has shown that the communal toilets are partly a success case. Open defecation has been reduced, but still not all villagers use toilets. The water consumption has been reduced to 1 l per toilet use and fertilizer is applied to grow paddy.

Reasons for success

Urine and manure are used for growing paddy. Every six months 500 kg of fertilizer are applied on the farmland. Only 1 l of water is used for anal cleansing and hence the toilet saves around 10–12 l of water. The toilets function well, but of 200 targeted people only about 80 people use them (the others still practise open defecation). Therefore, socio-cultural issues were further investigated.

Socio-cultural assessment

Twenty-two questionnaires were administered, through face-to-face interviews, to inhabitants of Asalthpur village, although only 18 questionnaires contained sufficient information for analysis. Table 4 below, provides a description of the sample investigated.

The problems with the toilet may be rooted in overuse – there is an average of 27 people using each toilet. The Sphere Project (2004) recommends a maximum of 20

Table 4 | Asalthpur sample description

Descriptive statistics	Sample Description	N = 18 respondents
Respondent gender	Female	72%
	Male	17%
Household density	Range	3–10
	Mode	5
Average number of children per household	Range	1–5
	Mode	2
Employment status	Employed	67%

people per toilet in emergency situations. In a development context, an even lower number of people per toilet would be expected. The high number of people per toilet will contribute to odour, and the small number of toilets for a large population will mean than some people will have to walk a long way to use the toilet.

All households where some or all of the household members used the toilet had received training from the local NGO. Of the four households that did not receive the training, two had no users of the toilet, and the other two had some users of the toilet.

The level of satisfaction among users was investigated: 50% of respondents considered themselves satisfied with the system, expressing a feeling of relief for not having to practise open defecation. Furthermore, 33% of respondents considered the toilet positive for their health. Users showed willingness to invest to improve the status of the toilets (44.5%), such as paying for disposal of excreta. Users' understanding of reuse components of the Ecosan technology was explored: 44.5% of the sample investigated agreed that there was a potential to use urine as soil conditioner, and human excreta as soil fertilizer. The remaining respondents were not sure about the possibility or preferred not to answer.

Among all respondents (both users and non users) 72% reported to have experienced problems with the Ecosan toilet. Multiple responses analysis was computed to identify the most common problems experienced. These are presented in Figure 7, below.

Households where some or all family members used the toilet had a positive problem solving attitude, with 70% reporting the problem to the NGO.

Users' behaviour in using the Ecosan toilet was also explored. Thirty-eight percent of respondents said they diverted urine in the appropriate chamber, whilst 61.5% stated that they did not divert urine. However 50% of users always covered their faeces with ashes after defecation.

Hygienic assessment

The user is largely unexposed to the contents of the dehydration vault but may be exposed during maintenance in levelling out the faecal cone in the vault and during emptying.

Both for sitting and squatting the floor of the toilet (e.g. the slab, the area around the pedestal, etc.) can act as an exposure pathway as excreta can be transferred to the hands or feet. After defecation the user washes using half a litre of water in an area provided for this purpose inside the room and this water is collected and diverted to a nearby field through a pipe. The user or the person responsible for cleaning may be exposed to faeces which may be deposited in the urine area and which must then be removed. Normally the risk of exposure to flies or other insects is low. If the material is properly covered and the pit is vented, exposure to flies and other vectors is minimized considerably. The urine should be diverted to ensure proper functioning of the dehydrating vault. The technical design and user's perception largely govern the degree of faecal cross-contamination and the subsequent risks of accidental direct exposure. The urine collection container should ensure that overflow does not occur, which may otherwise also lead to accidental direct contact.

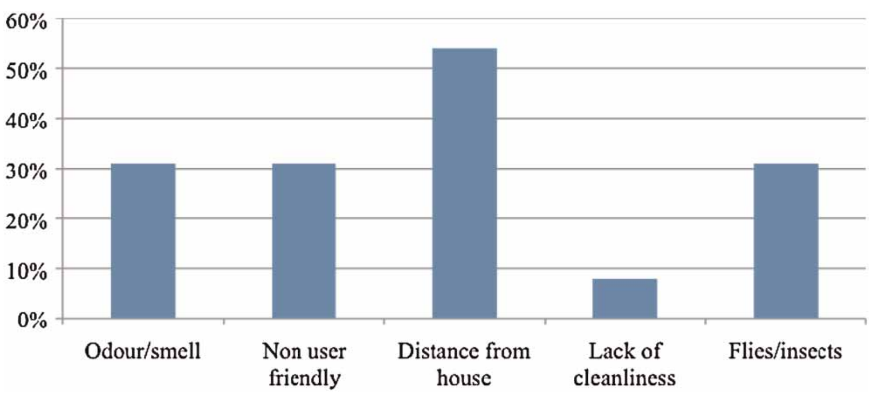

Figure 7 | Identified problems with Ecosan.

Biogas toilet

Initial assessment

The evaluation of the technology has shown that it was mainly a success. Biogas toilets have been built by each household for disposal of human excreta. The entire village is open defecation free as all households are using the toilets. Each house gets around 3–4 hrs of cooking gas per day, depending on how much cow dung is added and the family size. The pipes from which the gas is transported to the house are properly mounted. The pressure valves are well maintained. Some households have cooking gas linked toilets while some have toilets which are not linked to cooking gas.

The amount of slurry is very limited; it does not cause any unhygienic condition. After drying the slurry is converted into organic fertilizer. A separate ditch is dug for waste slurry collection. The ditch is well covered with dried grass. The O&M cost is almost negligible.

Reasons for success

The technology was implemented by the households on own initiative and costs. The village is free from open defecation and people accept the toilets as well as the generated biogas. Normally one family gets 3–4 hrs of cooking gas from human excreta. This reduces their burden on the gas cylinder which they have to purchase from the market. However, some people do not accept using the gas for cooking for religious reasons (this applies only to 3–4 households out of 51).

Hygienic assessment

Contact with the slurry is the most dangerous exposure pathway. Because the slurry is free-flowing it is often allowed to pour out of the reactor into a ditch directly on the land and sometimes directly to agricultural areas where then additional exposure may occur for people in direct contact with the material and for consumers of products fertilized with it. Even if partially treated, the slurry is unsafe and any type of exposure should be avoided. Frequency of exposure is high–medium for the user, depending on the slurry production and outlets and low–medium for the community, depending on slurry containment and outlet areas. The 'level of risk' is medium for the user and for the community, and may be elevated for the consumers of the products fertilized depending on the holding time in the reactor and the drying time of the slurry before use.

Socio-economic assessment

Biogas toilets cost, at the time of construction, about INR 10,000 and the construction time needed is about 18–20 working days. All respondents said the costs were affordable or even easily affordable. Some users stated that they would need some support for maintenance and estimated their current effort for O&M at ~1 hr per week. The biogas systems only deliver enough biogas if the family consists of 10 or more members, which has been the case for the majority of the interviewed households.

Solid immobilized biofilter (SIBF)

Results of initial assessment

The evaluation of the technology has shown that it was mainly a success case. The effluent complies with Indian norms, with values of 6 mg/l BOD (biological oxygen demand) and 20 mg/l COD (chemical oxygen demand), and the water is reused for irrigation of the school garden and toilet flushing. The system is working well and O&M costs are INR ~3 per m^3 treated water (compared to INR 20 for conventional treatment). The construction costs of the system in Kimmins, which has the capacity to treat 40 m^3 per day, were INR 1.7 million. The SIBF in Bharati is designed to treat 100 m^3 per day and the construction costs add up to INR 3.2 million.

Reasons for success

A main reason for the success is that the entire O&M is taken care of by a company and the costs charged by the company for O&M are reasonable for the school. The users are very satisfied with this technology because the treatment system is serving the intended purpose. The treated water is being reused for gardening and toilet flushing thus conserving the precious water.

Hygienic assessment

The main risks relate to the maintenance work, the irrigation and the contact with irrigated areas and treated water, but as it conforms not only to the norms for irrigation, but also to the surface water discharge standard, the risk for the operator is low. Moreover, disinfection is also carried out before the reuse of this water. The water used for gardening infiltrates through the soil naturally and is not put directly into the aquifer. The risk related to reuse in gardening and groundwater recharge is judged as low.

Multiple stage filtration (MSF)

Results of initial assessment

The treatment plant does not present any technical problems and users are satisfied to have this technology, which provides water for irrigation. However, there is no regular water testing to ensure that the discharge norms are complied with.

Reasons for failure

On the spot sampling has shown high organic contamination and hence that the treated water did not meet the standard for irrigation and also not for stream disposal. There is a possible risk to human health as the water is used in fruit farming and groundwater recharge.

Decentralized wastewater treatment system (DEWATS)

Results of initial assessment

The system is a success case. It is accepted by the users and performs well (effluent quality: BOD: 17 mg/l, COD: 50 mg/l, Oil and grease: 4 mg/l, pH: 8.0–27.2.2009).

Reasons for success

The system is well functioning, well used, and managed by the community. The users are collecting money for the maintenance of the system. The construction costs for one DEWATS systems (the one discharging to the green belts) were approximately INR 14.5 million: these costs are for all treatment steps. In the last two years O&M costs were ~ INR 1,500 per month: these costs cover the labour costs required for the disposal of the sludge of primary and secondary treatment steps and to maintain the plants of the tertiary step.

Hygienic assessment

This is an example of a well-designed system with little hygienic risk. Further risk reduction may be ensured by appropriate irrigation practices and crop selection.

CONCLUSIONS AND RECOMMENDATIONS

All systems are well accepted except for the communal Ecosan toilet, where users complained about the long distance to the systems. The hygienic risk is highest for the septic tank due to the high risk of direct contact during emptying and directly to community members as well where the pond, in which the septic tanks discharge as well as the water from handpumps, shows contamination. The biogas and Ecosan systems pose medium risk to the person who is emptying the systems, whereas the SIBF and the DEWATS feature only low risk as users do not have direct contact with the system. The effluent of the MSF is not complying with the norms for irrigation and the risk is judged to be medium dependent on the reuse irrigation practices and the type of crops planted. The biogas generated in the biodigesters can be used for cooking and SIBF and DEWATS produce effluent that is suitable for irrigation. Table 5 summarizes the results of the assessment.

Based on the results of the assessment the following conclusions and recommendations can be made:

- All on-site sanitation systems except for the Ecosan system were individual systems and well accepted by the users. The main constraint is the distance to the toilet systems,

Table 5 | Summary of results

	Septic tank	Ecosan	Biogas toilets	Multiple stage filtration	Solid immobilized biofilter	DEWATS
Social acceptance	Well accepted	Only partly fulfilled	Well accepted	Well accepted	Well accepted	Well accepted
Costs (construction/ O&M)	18,000 INR/1 hr per week	14,000 INR/no information	10,000 INR/ no information	No information/ no information	1.7 million INR (Kimmins); 3.2 million INR (Bharati)/3 INR per m^3	1.45 million INR (5,800 INR per HH)/1,500 INR per month
Hygienic risks	High risk	Medium risk	Medium risk	Medium risk	Low risk	Low risk
Environmental considerations	No reuse	500 kg fertilizer every 3 months	3–4 hrs cooking gas per day	Effluent does not comply with standard	Effluent can be used for irrigation	Effluent can be used for irrigation

which should be considered when building communal systems.

– Respondents' suggestions of improvements to the systems should be taken into account by engaging in a dialogue with users to understand their needs and discuss feasible interventions.
– Education on appropriate hygiene practices as well as the use of the systems as a way to improve aspects, such as smell and breeding insects, should be provided on an ongoing basis.
– In the two evaluated household on-site systems, the biogas system and the septic tank, the main risk is the sludge, which is difficult to handle. Professionally equipped workers are necessary to conduct the emptying of the biodigester and the septic tank.
– To assure that safe products are obtained from the biodigester, the temperature has to be high enough. In situations where both the heating and hydraulic retention time cannot be fulfilled, it is important that the product is treated further either in co-composting or with standardized drying.
– There exist successful examples of DEWATSs aimed at reuse of the treated wastewater.
– One factor of success of the decentralized systems is the well organized O&M, which is either conducted by a private company or a community committee. Another prerequisite is the coverage of O&M costs, which has been achieved in the case studies due to community contributions. Those decentralized systems also require less energy (and have therefore lower costs) than conventional treatment systems.
– Whereas the performance of the SIBF and DEWATS is controlled on a regular basis by MPCB and the Hunnarshala Foundation, the efficiency of the treatment is not tested in the MSF system in Kikwari. As all systems provide water for irrigation which users come in contact with, regular monitoring is required to keep the hygienic risks low.

ACKNOWLEDGEMENT

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