Evaluation of DEWATS in Java, Indonesia
S. M. Kerstens, H. B. Legowo and I. B. Hendra Gupta

ABSTRACT

Under the Indonesian PPSP (Accelerated Sanitation Development for Human Settlements Program) thousands of new DEWATS (Decentralized Wastewater Treatment Systems) may be realized in the coming five years. Taking the massive scale of planned implementation into consideration an evaluation of the technical and financial-economic aspects and users’ involvement for three different types of DEWATS was performed. Evaluated systems included (1) Settler (Set)+Anaerobic Baffled Reactor (ABR)+Anaerobic Filter (AF), (2) Digester+Set+ABR+AF and (3) Settler, equalization, activated sludge, clarifier, filtration. All three systems complied with the current regulations. System 3 suggested the best overall performance on selected parameters in the monitored period. A clear reduction in specific investment costs per household was found with an increasing number of households per system. Only daily, regular operational costs were recovered from fees collected by the community, whereas costs for desludging, major repairs and capital and replacement costs were not. Surveys with users showed a different degree of involvement of local men and women in the planning stages of the project for the systems. Recommendations are provided to scale up the introduction of DEWATS in a more sustainable way in the framework of a city wide sanitation strategy.

Key words | DEWATS, financial, Indonesia, performance evaluation, sanitation, technical

INTRODUCTION

Access to improved sanitation in Indonesia is below most other South East Asian countries, with an approximate 80 million people still using open defecation. The Water and Sanitation Program’s (WSP) Economic Impacts of Sanitation in Indonesia (WSP 2008) estimated the overall economic losses from poor sanitation at approximately US $ 6.5×10^9 annually. Decentralized communal treatment systems are often promoted as the core of the sanitation improvement in Indonesia for their low cost, their decentralized features as well as their potential to effectively remove organic components and solids (Ulrich et al. 2009). Limited up to date information is available on the actual sustained performance of applied systems. Mostly, the effluent of DEWATS (Decentralized Wastewater Treatment Systems) is discharged locally. Evaluation of the effluent is important with respect to safeguarding public health and the environment (Vollaard et al. 2005), in particular when the body receiving the effluent waters is having particular functions for which it must meet related water quality criteria. In addition, this paper compares the financial and economic aspects of the different systems as well the level of involvement of the users. Analysis from these three perspectives (technical, financial-economic and social) is considered essential for improved and accelerated access to safe sanitation, upkeep with population growth and sustained and equitable service delivery in Indonesia.

METHODOLOGY

Site selection

In consultation with the Ministry of Public Works (Pekerjaan Umum, PU), three municipalities in Java were
selected for evaluation. These were Yogyakarta, Surakarta (also known as Solo) and Blitar. In each of the municipalities three DEWATS were selected. Site visits were facilitated by local partner LPTP (Lembaga Pengembangan Teknologi Pedesaan or Institute for Rural Technology Development) in Yogyakarta and Surakarta and by the local bureau of environment in Blitar. Three types of systems were evaluated. The first two types are the commonly applied systems, whereas the third type seems to have been introduced only recently, but is gaining in popularity in the Blitar area. Because of its electricity use, this third type may not be classified as a DEWATS by all stakeholders (Ulrich et al. 2009). Table 1 shows the key features of the nine evaluated sites.

**Laboratory analysis**

For each site four samples were taken with the following schedule: Yogyakarta: 8, 17, 22 and 25 February; Surakarta: 9, 18, 23 and 28 February; Blitar: 16, 21, 24, and 28 February. February is the rainy season. All evaluated systems apply a separate rainwater collection. However, some

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of evaluated DEWATS project sites organized by system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System 1</strong>: Settler+Anaerobic Baffled Reactor (ABR)+Anaerobic Filter (AF)</td>
<td>Project name, province, Kota/Kabupaten (year); number of households (hh)</td>
</tr>
<tr>
<td>1. Minomartani, DYI, Yogyakarta, Kab. Sleman (2007); 70 hh.</td>
<td></td>
</tr>
<tr>
<td>2. Santan, DYI, Yogyakarta, Kota Yogyakarta (2010); 80 hh</td>
<td></td>
</tr>
<tr>
<td>3. Kragilan, Central Java, Surakarta, Kota Surakarta (2005); 100 hh</td>
<td></td>
</tr>
<tr>
<td>4. Sukorejo, East Java, Blitar, Kota Blitar (2003); 200 hh</td>
<td></td>
</tr>
<tr>
<td>5. Karang wetan East Java, Blitar, Kota Blitar (2006); 100 hh</td>
<td></td>
</tr>
<tr>
<td><strong>System 2</strong>: Separate black (BW) and grey water (GW) collection. BW of households (and MCKa) to digester; effluent of digester with GW to Settler+ABR+AF</td>
<td></td>
</tr>
<tr>
<td>6. Gambiran, DYI, Yogyakarta, Kab. Sleman (2008); no MCK applied; 50 hh</td>
<td></td>
</tr>
<tr>
<td>7. Pajang, Central Java, Surakarta, Kota Surakarta (2010); including MCK; 40 hh connected; 29 hh use MCK</td>
<td></td>
</tr>
<tr>
<td>8. Srenang, Central Java, Surakarta, Kota Surakarta (2008) including MCK; 22 hh connected; 44 hh use MCK</td>
<td></td>
</tr>
<tr>
<td><strong>System 3</strong>: Settler, equalization activated sludge, clarifier, filtration</td>
<td></td>
</tr>
<tr>
<td>9. Kepanjen Kidul East Java, Blitar, Kota Blitar (2010); design capacity 400 hh (only 100 hh connected at time of evaluation)</td>
<td></td>
</tr>
</tbody>
</table>

*aMCK: Mandi Cuci Kakus: Communal toilet and washing facility.*
rainwater intrusion may have taken place. All samples were analysed on the following parameters, with corresponding methods: pH (SNI 06-6989, 11-2004), biological oxygen demand (BOD) (APHA 2005, Section 5210-B, Section 4500-OG), chemical oxygen demand (COD) (APHA 2005, Section 5220-C), total suspended solids (TSS) (in house method, spectrophotometer HACH, DR 2010), total N (in house method, titrimetry), NH4-N (SNI 06-2479-2004), PO4-P (APHA 2005, Section 4500-PD), total coliforms (APHA 2005, Section 9221-B), faecal coliforms (APHA 2005, Section 9221-E). All samples were collected and analysed by the same laboratory (Balai Teknik Kesehatan Lingkungan (BTKL) in Yogyakarta). Influent samples were not taken because variations in quality and quantity are generally very high for small communities. Further, because all communities concern domestic users only, a comparable influent is expected.

Surveys and questionnaires

For each site two types of surveys were conducted. In a first survey representatives (all male) of each of the KSM (Kelompok Swadaya Masyarakat; ‘Community Independent Group’) were interviewed on technical, institutional and financial features of the sanitation facilities. In the second survey six local surveyors interviewed a total of 90 respondents (59% females and 41% males) at nine sampled locations, corresponding with 10 households per site. The topics were their involvement and satisfaction as users and tariff payers with the service delivery and service management (including financial management). All respondents were randomly selected and were part of the connected users in every DEWATS site. The age of the respondents involved in the survey was 28 years and older. Most of them were female (59%). Of these respondents, 11% did not have any formal schooling, 27% were elementary school graduates, 19% junior high school graduates, 30% high school graduates, and 13% university graduates. Most of the respondents’ monthly incomes ranged between US$50 and US$100 (49%), 28% of the respondents had an income below US$50, 17% of the respondents had incomes between US$100-US$200 and 7% of the respondents’ incomes were above US$200. Ninety-two percent of the respondents had never been involved in a survey before.

Financial and economic analysis

For each of the sites information on the capital and operational costs as well as the nature and level of the user’s fees were obtained during the discussion with the KSM and were – for reference – compared with the design documents. Construction costs included costs for the treatment plant itself, piping, digester (if applicable), MCK (if applicable) and facilitation (including training and project planning by BORDA ‘Bremen Overseas Research and Development Association’ and LPTP or the local bureau of environment in Blitar). Taxes have been excluded from the presented data. To allow for comparison all investment costs were converted to the year 2010 price level, using the inflation percentage provided by the World Bank (http://data.worldbank.org/) and the Consumer Price Index (CPI) provided by Badan Pusat Statistik (http://dds.bps.go.id/eng/). To calculate the annual Capital Expenditures (CAPEX), investment costs were multiplied with an annuity factor based on a depreciation period of 20 years and an interest rate of 7%, which can be considered as a typical rate for Indonesia (www.web.worldbank). Finally, the economic losses due to poor sanitation were calculated based on WSP (2008) and were corrected with the same CPI as mentioned above. The size of the population of Indonesia in 2010 was based on the 2010 Census and set at 238 million people. It is assumed that the household incomes obtained from the surveys are representative for the total community. In this study 1 US$ is equal to 9,000 IDR.

RESULTS AND DISCUSSION

Technical evaluation

Table 2 shows the effluent values of the three evaluated sites after four sampling rounds as well as the applicable effluent standard (MoE 2003). System 1 is based on five sites, the values of system 2 on three sites and the values of system 3 on one site only (see also Table 1).

Organic pollutants

All three types comply with the 2003 regulations on pH, BOD and TSS. However, current effluent requirements
are not very stringent, especially in comparison with applicable standards in neighbouring countries. Philippines and Malaysia apply BOD effluent requirements of 30–80 mg/l and 20–50 BOD mg/l respectively (DENR 1990; MDE 2000). More stringent effluent requirements and extension on number of parameters (e.g. nutrients) should be considered in due course following, for example, a similar approach as the progressively increased raised standards in Malaysia to improve, in order of importance, public health, water quality and environmental quality. The data suggest that system 3, involving activated sludge and filtration performs significantly better on all effluent parameters compared to the other two system types, although it must be noted that system 3 is currently only operated at a quarter of its design load. The effluent values of system 1 (Settler + ABR + AF) and system 2 (Digester + Settler + ABR + AF), however, are comparable. Taking the high standard deviations of all systems into consideration it appears that stable operation is hard to achieve. This variation is also observed in the individual sites. A pilot study (Dama et al. 2002) on the ABR showed COD effluent values ranging between 50 and 400 mg/l with steady state values of typically 200 mg/l. Current measured values on the two types of systems applying ABR are considerably lower than these values. Unlike in Dama’s study the currently evaluated systems have an additional anaerobic filter step, indicating that this filter contributes significantly to a better COD effluent. Wibisono et al. (2003) showed effluent COD values ranging from 80 to 144 mg/l COD in three piloted low-costs anaerobic systems in Indonesia, which are comparable to the values in the current study.

### Nutrients (N & P)

The lower NH$_4$-N values in system 3 as compared to the other two systems are attributed to nitrification in the activated sludge system. In addition, the lower total N values in system 3 are attributed to denitrification. System 3 was only operational for one month and nitrification capacity is expected to increase further. At the same time, because the system is under loaded the results may differ compared to treatment of the full design load. Although the effluent P-concentration in system 3 is lower than in system 1 and 2, 3, 4.8 and 3.8 mg/l respectively, the values are more comparable to each other than the other parameters. In general P is only removed to a limited extent in an anaerobic system. In aerobic systems, P-removal would require alternating anaerobic and aerobic conditions or the addition of iron or aluminium salts (Brett et al. 1997), none of which are applied. The lower effluent P-value in the aerobic system is attributed to the higher P-uptake by aerobic biomass compared to anaerobic biomass. The presence of P is the most common cause of eutrophication in fresh waters, with P-concentrations in streams of 20 μg/l already becoming problematic. Especially for smaller streams with multiple sources, such values are likely to be exceeded easily. In addition, with N/P ratios exceeding 16 (which is the case in all three systems) nitrogen also becomes a stimulant for eutrophication (Corell 1998).

### Coliforms

The amount of total (Figure 1) and faecal coliforms discharged by all systems is alarmingly high in view of both expected levels (Tchobanoglous et al. 2003) and

### Table 2: Average and standard deviation effluent values and effluent standard

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<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>pH</td>
<td>–</td>
<td>6.9 (0.3)$^a$</td>
<td>7.2 (0.3)</td>
<td>7.2 (0.5)</td>
<td>6–9</td>
</tr>
<tr>
<td>BOD</td>
<td>mg/l</td>
<td>49.7 (8.2)</td>
<td>50.0 (15.7)</td>
<td>29.9 (11.9)</td>
<td>100</td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>121.8 (21.9)</td>
<td>131.1 (53.1)</td>
<td>79.5 (39.5)</td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>41.7 (24.5)</td>
<td>43.6 (30.0)</td>
<td>21.8 (10.3)</td>
<td>100</td>
</tr>
<tr>
<td>Total-N</td>
<td>mg/l</td>
<td>77.1 (23.5)</td>
<td>88.0 (25.0)</td>
<td>58.7 (12.0)</td>
<td></td>
</tr>
<tr>
<td>NH$_4$-N</td>
<td>mg/l</td>
<td>46.0 (20.6)</td>
<td>57.4 (26.7)</td>
<td>34.7 (18.8)</td>
<td></td>
</tr>
<tr>
<td>PO$_4$-P</td>
<td>mg/l</td>
<td>3.8 (1.8)</td>
<td>4.8 (1.8)</td>
<td>3.0 (1.9)</td>
<td></td>
</tr>
</tbody>
</table>

$^a$Values in brackets are standard deviations.
safeguarding public health. However, the coliforms discharged in system 3 (Kepanjen Kidul) are significantly lower than the other two systems. Currently no maximum discharge limit is formulated in the applicable 2003 law for these parameters. The World Health Organization (WHO) has defined several standards for reuse (WHO 2006) in agriculture or aquaculture, which are exceeded even for system 3. The Indonesian drinking water regulation for 2010 (number 492) requires the complete removal of all coliforms. Several KSMs reported the perceived decrease of diarrhoeal diseases since the establishment of the DEWATS service, but no supportive actual clinical data could be provided. Reasons mentioned for the perceived decrease were both the reduced contamination of groundwater by previously applied and now replaced soakage/pit latrines and the reduced contamination of surface water with which women, children (especially boys) and men have direct contact during clothes washing, bathing and swimming. The quality of the discharged water is important from an environmental, economic and health perspective. Vollaard et al. (2005) concluded in their study of the supply and bacteriological quality of drinking water and sanitation in Jakarta that inadequate disposal of human excreta is a threat to both piped water and groundwater. Phanuwongan et al. (2006) showed the positive correlation between total coliforms and enteric viruses present in surface waters, showing the threat to protect public health from viral waterborne diseases. In addition, Charles et al. (2003) reported the increased discharge of total nitrogen (TN), Cryptosporidium and enteric viruses for small scale water treatment systems (compared to a centralized wastewater treatment plant (WWTP)) as a result of insufficient operation and maintenance knowledge for these small scale systems. Thus, as a recommendation more attention to removal of pathogens could be paid in the design of DEWATS and their operation, as these pathogens have a direct impact on public health. Several low-cost post-treatment systems can be considered that have known effective removal of pathogens and nutrients, such as constructed wetlands or algae ponds (Laxton 2010; Zhai et al. 2011). Mandatory disinfection to acceptable levels (WHO 2006) could also be considered if reuse is strived for.

Feedback from operators and users

Discussion with system operators and the users revealed several issues that require attention:

• Systems are hardly desludged, even after years of operation. However scum formation in the settling
compartment was grave and removal was required frequently (typically twice per month). Scum formation could be the result of attachment of biogas to incoming particles as described by Halalsheh et al. (2005). More frequent desludging could prevent this problem. This requires including the cost of sanitary desludging in the fees;

- Often, the removed scum and sludge were disposed of in the receiving water body. Besides the obvious contradiction of this practice to the objective of having a sanitation system, this approach is also a loss of potential safe fertilizer (Fach & Fuchs 2010). Mostly provisions to deal with this differently were lacking as sites were not reachable by vacuum trucks or costs for frequent scum removal in a hygienic way were found too expensive. This aspect requires more attention in the designs, promotion and training;

- System 3 is identified as the most vulnerable one during the operation and maintenance (O&M) phase, as more skilled labour and understanding of the system and its electro-mechanical equipment as well as continuous electricity supply are required to operate the system in a sustainable manner.

- Manholes for both the network as well as the treatment system were often jammed. This limits the possibilities to operate and maintain the systems properly;

- During rainfall several systems become odourous. Although systems are designed to separate rainwater from wastewater, it was observed that rainwater can penetrate the manholes, which can be prevented by slightly elevating the manhole lids in the design. Odour problems are probably caused by a reduced hydraulic retention time resulting in the discharge of not yet degraded organic (volatile) components;

- None of the systems was provided with an easily accessible sampling point (e.g. a sampling tap). It is suggested to include such a tap in new systems to facilitate sampling and monitoring the impact on the public health and environment. Further, it was mentioned that regular monitoring of effluent was not done or only in limited cases by either the responsible institutions or design or facilitation partners. If measurements were done, no feedback was provided to the community. More frequent monitoring and feedback to the community is recommended as this contributes to a better understanding of impacts and system performance;

- Finally, the KSM mentioned that in the design of the DEWATS, a citywide sanitation strategy was not taken into consideration, although mainstreaming of DEWATS is found to be a key element for sustainable infrastructure development (Ulrich et al. 2009). It is recommended to consider the application of a citywide sanitation strategy in the realization of DEWATS to both stimulate the introduction of DEWATS in systems where this is found feasible and, at the same time, limit introduction, where this is found less feasible.

### Financial-economical evaluation

#### Investment costs

Figure 2 shows that the specific investment costs per household decrease as an increasing amount of households connected to the system. This ‘economy of scale’ is seen both within one type of system (system 1 and 2) as well as for bigger systems in general. For system 1 (Set-ABR-AF) it was thus found that investment costs per household of a system for 200 households (US$ 240/household) are only approximately half of that of a system for 100 households (over US$ 460–490/household). This trend is not only found in the complete design (including piping, WWTP, facilitation, toilet blocks), but also in the specific investment...
costs per household for the piping system (Figure 3) as well as the treatment facility (Figure 4). The specific costs for the piping system for systems of type 2 (applying separation of black water and grey water) are considerably higher, because a double piping system is required. This is even more pronounced in the cases that combine individual house connections with an MCK (Srenang and Pajang), since in those cases the piping costs only reflect the connected households and not those that use the MCK. Based on these findings, it is recommended to look for opportunities to increase the scale of a treatment facility to reduce the investment costs. This could for example be achieved by having a joint DEWATS with two or more adjacent communities.

Presented findings are in line with previous studies which use a 1.5 times higher price for a separate black and grey water treatment system compared to a mixed wastewater sewer pipe (Kerstens et al. 2009). It is acknowledged that from this study it is not clear how costs will develop for bigger or smaller scales of system 3. However, decreasing specific costs with increasing household connections is plausible. The evaluated site of system type 3 is designed for 400 households, but is currently operated only for 100 households. A follow-up visit in August 2011 to system type 3 showed that more houses were getting connected. Therefore, for the investment costs for the sewer system the current sewer costs were multiplied by a correction factor of 3, following the calculated economy of scale in the evaluated systems via extrapolation.

Running costs (CAPEX+OPEX) and fees

In Table 3 the balance of costs (CAPEX+Operational Expenditures (OPEX)), benefits (from fees) and the cash deficit are presented for each site as well as the current fee/household/month and the fee that would be required to come to a full cost recovery including depreciation.

According the Sanimas (Sanitasi Masyarakat, or Sanitation by Community) approach (personal communication with BORDA) the level of fees should be based on all operational costs, being (a) daily operation and maintenance, small repairs, (b) local management and paid labour, (c) desludging, (d) large repairs and (e) replacement costs. Interviews with KSM, however, showed that only the first two (a and b) types of operational costs are seen as operational costs. As a result fees generally do not cover costs for desludging, large repairs or replacements. New connections are not paid from these fees, but are borne by the new household separately. The one exception where no fees are and will be collected is the case of system 3. The effluent of this system is expected to be of such good quality that it will be used as feeding water for a fish pond and that revenues from fish sale will pay for all types of costs of the service. As the fish pond was still under construction, this could not be verified and critical follow-up on the financial feasibility is recommended.
In addition it was found that fees were not adjusted during the years of operation, whereas inflation in Indonesia has been considerable, with an average value of nearly 7% since 2003 (http://dds.bps.go.id/eng/). It is recommended that in the determination of the fees all operational costs should be enumerated and yearly correction of fees following inflation is required.

Finally, it is found that operational costs (OPEX) are only a fraction (3–9%) of the total costs (CAPEX + OPEX). Table 3 therefore gives the (flat) fees that the users should be paying to meet all operational costs. Similar values of fees to meet full cost-recovery for a centralized system were confirmed in discussions with the director of Joint Secretariat (Kartamantul) of Yogyakarta. During that meeting it was confirmed that such values will not be accepted by users.

Table 3 | Cash balances of the evaluated sites and actual and required fees for break-even

<table>
<thead>
<tr>
<th>System</th>
<th>Project name</th>
<th>CAPEX Million IDR/year</th>
<th>OPEX</th>
<th>Fees</th>
<th>Cash Deficit</th>
<th>Actual fees IDR/month/HH</th>
<th>Required fee break-even incl. CAPEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1</td>
<td>Minomartani</td>
<td>35.8</td>
<td>2.0</td>
<td>4.6</td>
<td>33.3</td>
<td>5,000</td>
<td>41,500</td>
</tr>
<tr>
<td></td>
<td>Santan</td>
<td>29.0</td>
<td>1.2</td>
<td>4.8</td>
<td>25.4</td>
<td>5,000</td>
<td>31,500</td>
</tr>
<tr>
<td></td>
<td>Kragilan</td>
<td>41.3</td>
<td>1.5</td>
<td>3.6</td>
<td>39.2</td>
<td>3,000</td>
<td>25,600</td>
</tr>
<tr>
<td></td>
<td>Sukorejo</td>
<td>40.0</td>
<td>3.0</td>
<td>3.6</td>
<td>39.9</td>
<td>3,000</td>
<td>17,900</td>
</tr>
<tr>
<td></td>
<td>Karang wetan</td>
<td>38.8</td>
<td>1.2</td>
<td>3.6</td>
<td>33.4</td>
<td>3,000</td>
<td>33,400</td>
</tr>
<tr>
<td>System 2</td>
<td>Gambiran</td>
<td>29.2</td>
<td>1.2</td>
<td>1.2</td>
<td>29.2</td>
<td>2,000</td>
<td>50,700</td>
</tr>
<tr>
<td></td>
<td>Pajang</td>
<td>32.7</td>
<td>3.0</td>
<td>5.4</td>
<td>30.4</td>
<td>6,000 per HHC^a 500–1,000 MCK</td>
<td>43,200</td>
</tr>
<tr>
<td></td>
<td>Srenang</td>
<td>36.4</td>
<td>2.4</td>
<td>2.4</td>
<td>36.4</td>
<td>5,000 per HHC 500–1,000 MCK</td>
<td>50,600</td>
</tr>
<tr>
<td>System 3</td>
<td>Kepanjen Kidul</td>
<td>60.3</td>
<td>4.4</td>
<td>0.0</td>
<td>64.7</td>
<td>0</td>
<td>13,500</td>
</tr>
</tbody>
</table>

^aHHC: household connection; other users pay 500 IDR/toilet visit and 1000 IDR/washing.

Financial and economical evaluation

Presented results show that at this point the capital costs are not borne by the users and could therefore be considered to be not financially viable from the point of view of a project manager. Table 4 shows that indeed only a small percentage of the investment costs are covered by the community. The major part of the capital cost is provided by central, provincial and kota (city)/kabupaten government, which is the same for the centralized sewerage services in the more affluent parts of the cities. Figure 5 shows, however, that there is a trend towards a higher contribution of the community to the investment costs from those with higher household incomes.

In 2008 the World Bank calculated that the economic losses due to lack of access to sanitation of 43% of the
Indonesian population were $6.5 \times 10^9$ US$/year, mostly as a result of accumulating health costs (53%) and (drinking) water costs (24%), whereas the yearly gains upon improving this situation would be $5 \times 10^9$ US$/year (WSP 2008). The Internal Rates of Return for the Indonesian Government to invest in providing sanitation to the not yet connected population using system 1, 2 and 3 are respectively 71, 38 and 155%. Liang & Van Dijk (2010) showed that the use of Decentralized Sanitation and Reuse (DESAR) systems in Beijing, China, is economically but not financially feasible as well. A similar study (Alam & Marinova 2005) showed the often underestimated economic benefits for intervention in environmental protection. It is concluded that from a perspective of net economic gains, greater government investments in improved sanitation services would be a wise decision. Methods to also calculate all costs that must be covered to sustain an adequate service delivery are being developed and tested elsewhere (Fonseca et al. 2010).

It was found that fees are the same for all users and no progressive fees were applied (e.g. a higher fee for people with a higher income) or a fee based on a higher water consumption (to reflect the polluter pays principle). As shown in the next section, the poor, with an average income of less than US$2 per day, formed 28% of the household sample, while households with a daily per capita income of US$7 or more formed 24%. Households in the first group tend to have only one tap and toilet, while households in the highest income category are likely to have more than two wastewater amenities and produce a much higher volume of wastewater than the first. Yet both categories contribute the same amounts to the investment and recurrent costs of the service.

The currently adopted and promoted cost sharing system thus disproportionally benefits the better-off and it would be fairer to use a weighed system whereby households with 1–2 rooms or a ‘low-volume house’ pay less than households with more rooms or with a medium- or high-volume house. Participatory rapid appraisal methods are an easy and well-accepted way to develop a more equitable and community-agreed tariff system (TTPS 2009).

**Evaluation by the user households**

Figure 6 shows the results of the user households’ involvement in the different stages of the service and in the decisions on the type and level of the monthly fees per type of evaluated system. It is the intention to further segregate this data by socio-economic level and for women and men in a later study.

The involvement of the community at an early stage is highest for system 1, followed by system 2 and finally in the latest type of system 3 the community is far less involved in the planning and implementation phase, and only becomes more involved from the operational phase. In addition, for both system 1 and 2, the community determines the price for new connections, whereas for system 3 this is done by an external contractor. For all systems new connections are largely paid for by the users themselves.

The participatory implementation of DEWATS systems was found to enhance the process of acceptance and management of the applied technologies. Implementation of DEWATS systems in Indonesia is based on a demand-response approach, whereby only those communities showing willingness to participate in planning, training activities and to manage the costs and operation and management (O&M) are selected (Roma & Jeffrey 2010). Because of the direct involvement of the community at – in principle – each keypoint of the project cycle (especially in local decision-making and in O&M, including financing management) these DEWATS systems are also known as Sanimas and the inclusion of local economic and social aspects is part of the widely accepted approach (TTPS 2009). It seems that in the approach followed by BORDA and its local counterpart LPTP, who are responsible for the design and facilitation, a more intensive community...
Figure 6 | Results of the user surveys.
involvement is applied compared to what was applied by the
design party of system 3 (Konsultan Pyramida Utama).

Moreover, all heads and the majority members of the
KSM were male, whereas women made more use of and
are more involved in daily system operation. It is suggested
to have more women involved in the KSM to include their
experience as well. Further, improvements in informed
decision-making to facilitate the recovery of costs and
equity of financing are recommended.

The most important (perceived) benefit of the users of
system 3 is improvement of the environment, whereas
fewer benefits are seen in improved public health or
improved water quality of dug wells. Possibly this relates
to the fact that this community, in comparison with the
other system users, makes only little use of dug wells and
mostly relies on deep wells, which are less susceptible to
contamination and have lower risks to health than dug
wells. Alternatively, it could indicate a less effective aware-
ness campaign delivered by the facilitator. In general, all
visited communities were (very) satisfied with the DEWATS.

CONCLUSIONS

Three different DEWATS used in Indonesia were reviewed,
each with different technical designs, financial and econ-
omic parameters and different levels of community
involvement. The summary of findings and the main con-
cclusions on technical, financial-economic and community
involvement are, respectively:

- The evaluated DEWATS systems all complied with the
current Indonesian regulations, although these effluent
standards are not very stringent compared to those of
neighbouring countries. System 3 (activated sludge)
showed the best effluent quality on evaluated parameters
COD, BOD, TSS, N, P and coliforms whereas the other
two systems were more or less equal to each other.
High coliforms and nitrogen effluent concentrations
pose a threat to public health and the environment with-
out corrective measures. More attention to O&M and
training and site specific constraints in the design phase
are recommended. Although, system 3 (activated
sludge) comes out most positive, further study of this
type of system is recommended as only one system was
evaluated and because it is identified as the most vulner-
able system in the O&M phase.

- DEWATS servicing the smallest communities (system 1
Dig-Set-ABR-AF) showed the highest investment costs
per household, followed by the system providing larger
communities (system 2 Set-ABR-AF) and system 3 (Set-
Act Sludge- Filter). This economy of scale effect is also
seen in the piping system and the treatment section only
and it is recommended to look for ways to increase the
scale of DEWATS. The users usually only cover the
direct operational costs. By not desludging they avoid
having to pay for these costs, which they are expected to
meet as well. Their share in capital costs, typically more
than 90% of the overall costs of the service, is very limited
and does not reflect differences in socio-economic levels.
Government investment in DEWATS systems specifically
and in environmental protection in general would have
substantial economic benefits and rates of return. For sus-
tained and equitable service delivery a greater share of the
user communities in recurrent cost financing is needed.
Better informed community decisions are needed on
ways in which financing can reflect the variation in dis-
charge more equitably (‘polluter pays’ principle). This
also goes for the regular adjustment of fees to higher recur-
cent costs because of inflation and system aging.

- Systems 1 and 2 have a bigger involvement of the commu-
nity in the planning and implementation phases of the
projects compared to system 3. In all cases the commu-
nities acknowledge the positive effects of the system
and show a great level of satisfaction with the system.

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