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Septage treatment in Indonesia: lessons from field investigations in seven cities

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More than 80% of urban households in Indonesia have access to sanitation, mostly provided by on-site facilities. This creates a need for septage management systems, including treatment. The Government of Indonesia has provided septage treatment plants in over 100 cities but few of these operate as intended and many no longer function. The paper describes assessments undertaken to establish the reasons for poor performance and to identify appropriate responses. The focus is on design but the paper also identifies concerns about the lack of relevant information and the need to tackle design and management challenges in an integrated way.

Background

More than 80% of urban Indonesians have access to sanitation, with 73% of facilities classed as improved and 10% as shared (UNICEF/WHO 2012). Almost all are on-site systems, with excreta flushed from a water-seal toilet to a leach pit and separate sullage discharge to a nearby drain. In recent years, Government and other stakeholders have built some local sewerage schemes connected to decentralized wastewater treatment facilities (DEWATS). In all these systems, faecal sludge accumulates in the pit or tank and must eventually be removed and treated.

Recognizing the need for improved septage treatment, the Directorate General of Human Settlements of the Ministry of Public Works (MoPW) is currently rebuilding or renovating septage treatment facilities in more than 100 cities. Unfortunately, less than 10% of the 150 sludge treatment facilities constructed in the 1990s were still functional by 2009, and less than 4% of Indonesia's septage was treated at a treatment plant (AECOM and SANDEC 2010). In the light of this, MoPW requested technical assistance from WSP and USAID to develop improved septage management systems, including improved septage treatment. This briefing paper summarises lessons learnt from WSP's assessment of septage treatment facilities in selected medium-sized cities from 2012 to date. The assessment covered:

- Complete septage management systems, including treatment facilities, in four cities: Jombang in East Java, Tegal in Central Java, Metro in Lampung Province at the southern end of Sumatra and Palu in Central Sulawesi. The city populations ranged from Jombang's 137,000 to Palu's 337,000 (2010 census data to nearest 1000). The focus here is on investigation into treatment plant design and performance.
- Septage treatment facilities in three cities; Tabanan (Bali) Balikpapan (East Kalimantan) and Tegal (Central Java). The team also visited Samarindra, the provincial capital of East Kalimantan, to obtain information on its under-construction septage treatment plant. The populations of Tabanan, Balikpapan, and Samarindra were 421,000, 640,000 and 725,000 respectively. (2010 census data)

Septage treatment plant arrangements

Septage treatment plant arrangements found in cities are summarised below:

Screening – provided in some but not all plants, usually incorporated into the first unit in the treatment process. (Palu, Samarindra, Jombang and Tabanan).

Solids – liquid separation Facilities found in the cities visited include:

- Imhoff tanks (Palu and the original Metro design but omitted in the under-construction Metro refurbishment). They are a feature of many older plants.
- Direct discharge to drying beds (Balikpapan), with percolate discharged to waste stabilization ponds.
- Solids – liquid separation chambers or SSCs (Tabanan – four SSCs in parallel.)
- Direct discharge to anaerobic waste stabilization ponds (Tegal – two ponds arranged in series)
- Domed bio-digester followed by 'sludge stabilization and separation tanks', in effect a series of sedimentation tanks arranged in series (/Bogor)

The new Samarindra plant will separate solids and liquid in a single deep tank, with solids piped to sludge drying beds.

Figure 1 is a longitudinal section through one of the Tabanan SSCs.

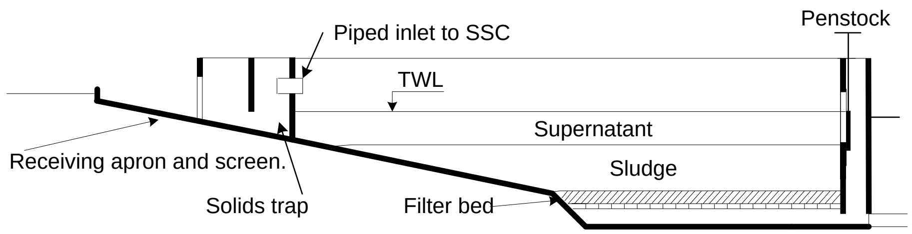

Figure 1. Longitudinal section through Tabanan solids-liquid separation chamber chamber

Treatment of the liquid fraction All the treatment plants treat the liquid fraction in anaerobic, facultative and maturation ponds. Jombang also includes a horizontal flow constructed wetland.

Treatment of the solid fraction All the treatment plants incorporate sludge drying beds, some of which are covered to improve performance during rainy seasons. Tabanan has a single large bed: approximately 25 metres long by 10 metres wide and described as a sludge drying area in the drawings and standard operating procedures (SOPs).

Disposal/use of treated liquid and sludge In most cases, a pipe or channel connects the outlet from the last maturation pond to a nearby watercourse. In many cases, this pipe or channel is dry because evaporation/seepage from ponds exceeds septage discharge to the ponds.

Dried sludge removed from the drying beds is usually stored on site or removed to a solid waste dumping facility/landfill. To date, no city has attempted to treat dried sludge further, for instance by composting, to render it suitable for use as a soil conditioner.

Why do septage treatment plants fail? Findings from field visits

The field visits identified the following reasons for the poor performance of existing septage treatment plants.

1. **Over-estimation of septage volume and strength**, resulting in underloading of the septage treatment plant.
2. **Design shortcomings**, including failure to recognize need to consider shorter-term loading, use of inappropriate design standards, failure to use any recognizable design standard, inappropriate technology choices and poor design details. These shortcomings make operation and maintenance tasks difficult to perform;
3. **Lack of the knowledge and skills** required to operate and maintain the treatment plant; and
4. **Inadequate management** systems.

This paper deals mainly with points 1 and 2. Points 3 and 4 are briefly considered at the end of the paper.

Over-estimation of hydraulic and organic loading

In all the study cities, the volume of septage delivered to septage treatment plants is much smaller than assumed by designers. One possible explanation for this is that tanker drivers, particularly those from the private sector, dump sludge indiscriminately or sell it to farmers for use as a soil conditioner/fertilizer. However, our investigations suggested that, although such practices do occur, they are usually less important than lack of demand for pit and tank emptying services. In Palu, where the septage manager keeps good records and there are no private sector septage vacuum tanker services, the municipality empties about 1400 pits and tanks each year, of which around 1200 are at private houses. This figure is only a small fraction of the estimated 51,000 to 70,000 household pits and septic tanks in the city, giving a clear indication that demand is limited. Records for Metro are poor but the absence of local private sector operators, despite the small number of pits emptied by the one municipal vacuum tanker, is indicative of low demand for sludge removal and transport services. In Tegal, most private sector tankers are underutilized, typically collecting sludge from only 2 -3 pits per week. The first entrepreneurs did make reasonable profits but profit margins dropped quickly as more competitors entered the market, creating an excess of supply capacity over demand. Again, the situation provides clear evidence of lack of demand.

A follow-up survey of 190 pits and tanks in 6 cities including Palu, provided further corroborating evidence of low demand for pit emptying services: 59% of the pits, with an average age of 15 years, had never been emptied. The actual proportion of never-emptied systems was probably higher since the study was restricted to systems with pit access, which were more likely to have been emptied than those without access. The average time to first emptying was 16 years but a second emptying was then required after an average of only 2.4 years. The sludge depth averaged 45% and 17% of total pit/tank depth at first and second emptying respectively. Taken together, these figures suggest that pits are often emptied because the percolation mechanism has failed rather than because the pit is full of sludge (Mills et al 2014).

For designers of septage treatment plants, these findings have two important implications:

1. The volume of faecal sludge removed from pits is likely to be much smaller than the total volume of faecal sludge produced and accumulating in pits
2. Septage is likely to contain a high proportion of water and thus have lower biochemical oxygen demand (BOD) and suspended solids (SS) concentrations than suggested in the mainstream literature.

Findings relating to design

Designs must take account of short-term loading conditions

The consequences of designing only for the assumed loading at the design horizon are evident at several of the treatment plants investigated. At worst, the volume of septage discharged is insufficient to fill treatment units. Photograph 1 shows the first anaerobic pond at Metro, where the low hydraulic loading, combined with leakage from the bottom of the pond, means that the pond is almost empty during dry weather.. All subsequent ponds receive no flow and are overgrown. In Palu, water does pass through the ponds but the ‘anaerobic’ ponds are light green in colour, indicating that they are performing in facultative or even maturation pond mode.

Photograph 1. Underloaded Metro anaerobic pond

Photograph 2. Operators struggling to move SSC outlet penstock

Operators at Tabanan try to follow standard SOPs provided by the plant designers. The SOPs assume a design loading of 27.4 m^3 of septage per day and involve the following steps:

- Load each SSC for four days with the penstock set to provide a water depth of 1.5 metres above the filter bed. Then transfer loading to the next SSC.
- Leave contents of SSC to settle for a further 3 days before lowering the penstock and allowing supernatant water to drain off to the first anaerobic pond. Pump the sludge remaining in the SSC to the drying area, using a submersible sewage pump.
- Leave the sludge in the drying bed for 4 days and then remove it by hand and store it within the plant boundary, leaving it to dry further. The SOPs allow 4 days for the labour intensive removal task, which requires up to 17 daily contract staff equipped with spades and wheelbarrows.

It should be possible to follow this cycle for the first and third SSCs simultaneously and then switch to the second and fourth SSCs. In fact, only two of the SSCs were in use at the time of the visit but the principle remains the same. When requested to lower the outlet penstock, operators had to use considerable force to move the penstock, even after applying grease. (See Photograph 2). The light green colour of the 'anaerobic' pond receiving the liquid fraction from the SSC indicated that it was very lightly loaded. The likely explanation for these observations an SSC does not fill over the prescribed four day filling period at the current hydraulic loading rate. There is thus little or no flow over the penstock. After the prescribed three days settling period, the operators pump a mixture of sludge and supernatant water to the drying area without lowering the penstock. The flow to the first pond thus consists mainly of the small volume of that drains through the porous base of the SSC, perhaps supplemented by a small amount of overflowing supernatant water: hence the light colour, which is indicative that the pond is lightly loaded. In view of this, there is reason to doubt whether the filter bed detail shown in Figure 1 fulfills any useful purpose. Operational performance would be improved by loading each SSC for longer than the prescribed four-day loading period and allowing supernatant water to follow over the penstock to the first anaerobic pond. This would make better use of the capacities of both the SSC and the anaerobic pond.

Design standards and practices

MoPW has developed a draft document setting out recommended design standards for various septage treatment units. In the absence of information relating specifically to septage, this document generally recommends the organic and hydraulic loading rates used for wastewater. There are some problems with this approach. In particular:

- Conventional Imhoff tank designs assume removal of digested sludge at intervals of four to six months. Given the relatively high SS content of septage, the volume of sludge deposited during this time in tanks treating septage is likely to be much higher than that in tanks treating wastewater. The higher rate of sludge deposition may lead to operational problems. Field investigations and interviews with operational staff provide some evidence to support this hypothesis. Imhoff tank desludging pipes block frequently while some operators report that it is not possible to desludge Imhoff tanks without adding water to the tank.
- Empirical design guidelines for wastewater treatment typically recommend a maximum loading of 350 gm BOD5/m3.d per day. There is some evidence that a higher loading is appropriate for design of septage treatment plants. Experimental work by Uddin (1970), reported by EAWAG, revealed that BOD removal peaked at a loading of about 750g BOD5 / m3.d for retention periods over 2 days. This finding is consistent with the 700g BOD5/m3.day design figure adopted for loading on an experimental septage treatment anaerobic pond system at Maximo Paz in Argentina (Fernández et al 2004).

No matter how appropriate the design guidelines, they will only be effective if consistently applied. Analysis of the treatment plants visited shows that units are often larger than theoretically required by the design guidelines. This suggests that designers do not always use generally accepted design standards to size treatment units. With assistance from WSP-World Bank, MoPW is responding to this by producing revised design guidelines for septage treatment, taking account of the points bulleted above. However, there will still be a need to ensure that designers follow the revised guidelines.

Design details

In Indonesia, as in other countries, designers often pay insufficient attention to design details. Poor details create barriers to good operational practice because operators are much less likely to follow standard operational procedures if the design creates difficulty in following those practices. Examples of poor design details identified during fieldwork include:

1. Steep access roads, sometimes without provision for turning;
2. Screens that are difficult to rake;

3. Designs with solids 'traps' and/or inadequate provision for sludge removal, leading to sludge accumulation and a need to decommission units while the sludge is removed, usually by hand.
4. Reliance on sludge pumping rather than the cheaper and more reliable option of using hydrostatic pressure to remove sludge from a sump at the bottom of a unit.
5. Use of vertical-sided waste stabilization tanks rather than ponds, with no ramps or steps to allow access for desludging
6. No provision for easy removal of blockages in interconnecting pipework between treatment units
7. Use of a single sludge drying area rather than sludge drying beds, necessitating removal of a mixture of dried and fresh sludge and complete cessation of sludge flows to drying beds during periods when sludge is removed from the ponds.

Examples of these deficiencies, identified during the course of the fieldwork, are given on the following page.

Inadequate access: Steep access roads caused problems at Tegal, Balikpapan and Bogor. At Tegal, tanker drivers were discharging sludge directly into maturation ponds, partly because of difficulties in negotiating the steep access to the designated discharge point and perhaps also because the pipes between anaerobic and facultative ponds were blocked. At Bogor, plant commissioning had been delayed because the access ramp to the discharge point was so steep that tankers could not use it. Even after remodelling, the access ramp was still very steep. While the access road to the discharge point at Balikpapan was also too steep, the main problem cited by tanker drivers was the absence of a turning area, which meant that they had to back out down the steep access road after discharging their load.

Screens Photograph 3 illustrates two common design weaknesses. First, the use of a vertical screen rather than inclined screen, which makes raking the screen difficult and second, the failure to think about how the operator can access the screen to rake it. The result is that solids block the screen and cause the water level to build up until an operator enters the chamber to remove the objects caught on the screen by hand. This is clearly an unhygienic and unpleasant practice. Figure 2 shows the recommended layout for a hand-raked screen, with bars sloped at an angle of about 60 degrees to the horizontal and bent over at the top to allow screenings to be raked into a trough, from which they can easily be removed. A platform is provided behind the screen to allow operator access for raking.

Photograph 3. Vertical screen with no operator access

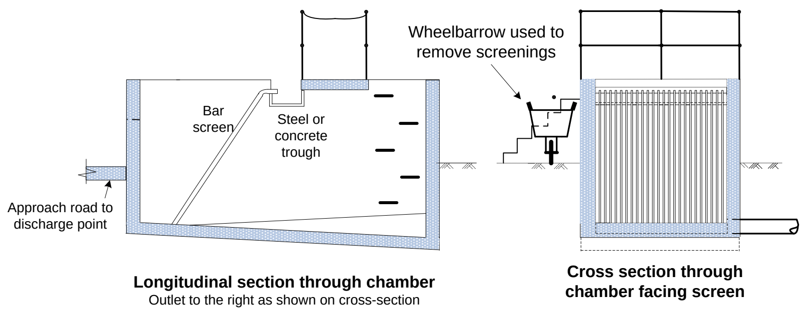

Figure 2. Screen designed for easy access and screenings removal

Solids traps and inadequate provision for solids removal Solids will settle wherever the flow velocity drops. If this happens at locations other than those intended by the design, the settled solids will require removing. The left hand side of Figure 1 shows the inlet arrangement to the Tabanan SSCs. Septage is discharged onto the apron, passes through the screen (which is vertical and unfortunately difficult to rake), under a cross-wall and through a higher-level pipe in the SSC end wall. Solids will settle below the pipe to the SSC, at the point indicated on the figure as a solids trap. The configuration is such that removal of solids will be difficult.

Old British wastewater treatment textbooks describe upward-flow sedimentation tanks for use in small wastewater treatment plants. These have no moving parts and are hopper-bottomed as shown by Figure 3. The hopper sides must slope at an angle of at least 60º to the horizontal. Otherwise, sludge will 'hang up' on the sides of the tank, allowing 'piping' channels to develop, through which supernatant water rather than sludge will find its way to the desludging pipe. The gently sloping bottom of the Bogor bio-digester has insufficient slope to prevent this phenomenon and it is no surprise that operators report that they have to desludge the bio-digester by hand.[1]

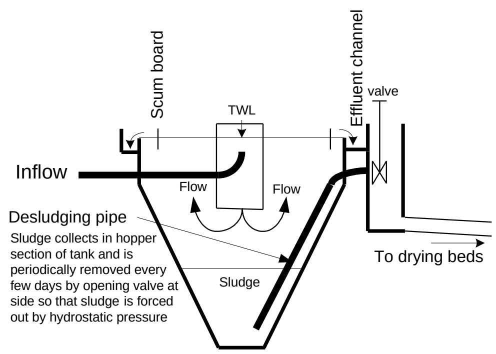

Figure 3. Hopper-bottomed sedimentation tank

Use of tanks rather than ponds. At Tegal, a new treatment plant comprising a series of waste stabilization tanks has replaced a larger pond system. Calculations show that the plant design is theoretically undersized and it is already showing signs of overloading, even at the small loading that it currently receives. The use of vertical-sided tanks, without steps, makes access for periodic desludging difficult and there is a high probability that staff will neglect regular tank desludging.

Provision for clearing blockages. Operators report frequent problems with pipe blockages. At Tegal, which has no screening, interconnecting pipes between treatment units were blocked. While good screen design, facilitating frequent raking, should reduce the incidence of such problems, the viscous nature of sludge makes it difficult to eliminate them completely. Designers should therefore ensure that all pipes can be rodded or otherwise reached to clear any blockages that do occur. Where this is difficult, they may explore the option of replacing pipes with channels.

Use of a single sludge drying area. The Tabanan design replaced existing drying beds with a single sludge drying area. This was a retrograde step. Separate drying beds are required in sufficient numbers to ensure that there is always time to dry and remove sludge before the next load is applied.

Operator knowledge, skills and management systems

The following points are important:

1. Operators are usually low-level municipal employees, unqualified with limited education, knowledge and skills. This must be borne in mind when selecting technologies.
2. Practical standard operating procedures are required. Some of those seen during the course of the fieldwork read like academic treatises. The SOPs need to tell the operators clearly and succinctly (a) what they should do (b) why they should do it and (c) how they might vary operational procedures if site conditions and factors are not as assumed by the designers. Sketches, diagrams and photographs can illustrate important points, particularly those that are difficult to explain verbally.

3. Institutional arrangements should provide managers with incentives to improve their knowledge and some prospect of advancement through a management hierarchy.
4. Support systems for municipal managers would contribute to improved outcomes. These should cover operational requirements and should also develop information systems, to be used for both design and subsequent operation and maintenance (for instance information on septage strength).

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Note/s

[1] The Bogor biodigester design is shown on the 11th slide of the presentation at http://unapcaem.org/Activities%20Files/A01/Treatment%20of%20sludge%20from%20domestic%20on-site%20sanitation%20systems%20septic%20tanks%20and%20latrines.pdf. The difficulty experienced in removing sludge is shown on a slide in a presentation by Thomas Hoffman of BORDA at the FSM 3 Conference, held in Hanoi, Vietnam in January 2015.

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