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Assessing on-site systems and sludge accumulation rates to understand pit emptying in Indonesia

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Despite 85% urban residents in Indonesia using on-site sanitation, demand for pit emptying is low and there is a lack of empirical data on local conditions. The type of system, sludge accumulation rate and pit emptying frequency was analysed from 190 household surveys, measured content of 107 pits and government interviews in six Indonesian cities. The sludge accumulations rates were on the low end of existing literature, with an average rate of 25l/p.y. 83% of the sample were single pits with an unsealed base receiving only blackwater and 22% had an overflow to a waterway or drain. The majority of systems had never been emptied. First emptying at 45% sludge depth occurred after an average 16 years, however subsequent emptying occurred more frequently at 2-4 year intervals. Planning on the basis of actual sludge accumulation rates could lead to more viable pit emptying business models and appropriately sized treatment plants.

Introduction

With less than 2% urban sewerage coverage, on-site sanitation is the main method of wastewater disposal for Indonesian's 110 million urban population (World Bank, 2013). Although the Indonesia Government's *Acceleration of Sanitation Development in Human Settlements (PPSP*) Program plans to increase sewerage coverage to around 6%, the widespread use of on-site sanitation systems in urban areas will continue. Prior field investigations by WSP found low emptying rates from on site systems, low loading of sludge treatment plants and questionable quality of on-site systems which highlighted the need for this study.

Existing sludge accumulation includes that from studies in Canada, USA, Ethiopia and detailed recent research in South Africa.[i] These studies found that many variables influence the pit filling rates and that estimates are best based on locally available data. The following variables differ from those in other study locations and could influence the sludge accumulation and pit emptying rates in Indonesia:

- **Higher temperatures:** Average temperature of 27degrees is higher than most previous studies and could increase the metabolic rate of digestion resulting in less sludge (Franceys et al 1992);
- **Low addition of solid material:** Anal cleansing with water is common across Indonesia, including for non-Muslims. This reduces solids addition to the pit, as compared with paper or material wiping. Additionally less rubbish is added to water sealed toilets than to the open pits assessed in the African studies (Still and Foxon 2012);
- **Wet contents:** Due to high groundwater and water added for flushing and anal cleansing, contents are typically wet. This causes anaerobic conditions and the high moisture content is likely to reduce final sludge volumes; and
- **System Design:** The settling and digestion of sludge in a single chamber leach pit is different to that in a standard septic tank due to surface area, volume and no use of tee or baffles which could cause different flow paths reducing contact with biomass in settled sludge and short circuit of flows direct to the overflow is possible in systems with overflow pipes.

This research assessed the quality of on-site systems, volume of sludge to be managed and frequency of system emptying to understand the technical influences on low emptying rates. Data from the research provides an actual basis for the current projects by development partners working with Government to improve faecal sludge management and the design and improvement of faecal sludge treatment plants which the Government of Indonesia has committed €7.4 million in 2014[ii].

Methodology

Accumulation rates were studied in six cities across Indonesia were surveyed: Bogor (West Java), Banjarmasin (South Kalimantan), Banda Aceh (Aceh), Makassar (South Sulawesi), Palu (Central Sulawesi) and Ambon (Maluku), with short additional visits to sanitation projects in low income areas of West Jakarta (West Java) and Belawan, Medan (North Sumatra). The cities were selected to include varied population and density, topography, soil type, groundwater levels and challenging environments (ie. above water, swamps, flood prone, etc).

Surveys included 190 household questionnaires to understand toilet and water use and previous emptying, and 107 technical assessments of accessible on-site systems, covering type, quality of construction, and to measure dimensions and contents (depth of sludge, liquid, scum and freeboard). The government wastewater authority, their operation staff and five private pit emptying providers were interviewed to understand emptying service, demand for emptying, typical systems, and the operation of sludge treatment plants.

Limitations of the study include the need to assess systems which had ready access, this biased the study towards systems requiring emptying; surveys only in cities with an existing sludge emptying service and treatment plant; sludge measurements were one-off at a single point; and the laboratory analysis limited and of low accuracy. Despite these issues, the data was sufficiently consistent in quantity and quality to determine typical rates for Indonesian conditions.

Results and discussion

On-site sanitation systems

With the interchangeable use of *"tanki septik"* and *"cubluk"* (Indonesian word for leach pit), the national survey finding of 72% septic tanks does not accurately reflect the type of on-site systems used (BPS 2013). Of the 178 systems surveyed that could be classified:

- Only **8% were conventional septic tanks,** brick or concrete built with a sealed base and more than one chamber. Only about half of these discharged to a soak pit as required by standard practice.

- Most **(83%) were single pits that leach liquid to the ground** through an unsealed base. Some had permeable pit linings, such as coral or wood.

- Small fibreglass tanks (6%) were found in new housing estates and trial projects in high water areas, often discharging directly to waterways. These were referred to as "*biofil"* however most had no filter media.

- **Outlet pipes to a drain or watercourse was found from 22% of systems,** as most systems lack tee inlets short-circuiting is likely, resulting in performance comparable to direct discharge. As described below, have half the sludge accumulation of systems without outlets.

In areas of deep groundwater the contents of the unsealed systems were drier and required the addition of water and stirring to remove the contents by vacuum truck. The average system had a volume of $2m^3$, served five people and received only blackwater from pour flush squat toilets. The average distance from on-site systems to a household well was 10m, creating a risk of groundwater pollution, particularly where the water table is high. However, use of groundwater for drinking was very low.

There is generally a poor understanding of adequate and appropriate on-site systems, with design errors in government drawings, and no established responsibility for promotion or enforcing quality systems. Most users sought to build systems that were "large and leaking so they will never require emptying". As a result very few systems had access covers and 20% of systems were located under the house.

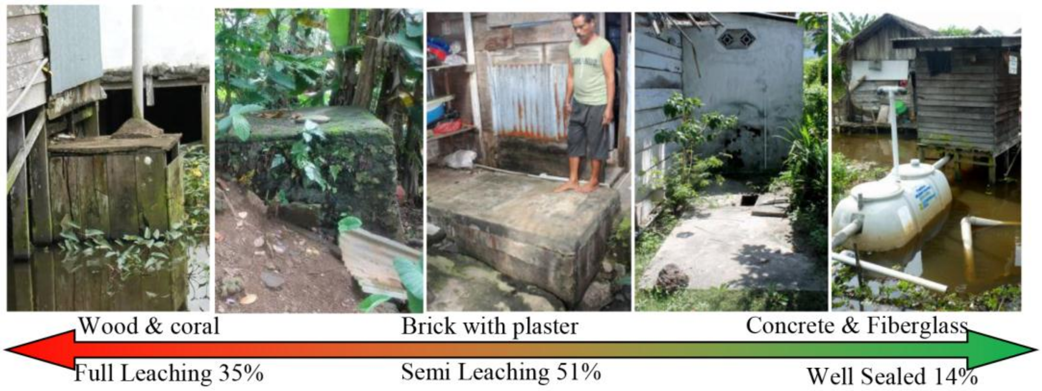

Figure 1. Type and quality of on-site system

Pit emptying

Based on government records of the number of pits emptied per year and assuming a five year emptying interval, an average 6% of households with on-site systems in surveyed cities had been emptied. This varied from lowest of 0.2% households in Banjarmasin where most pits are wooden, leak and are submerged in water; to the highest emptying coverage in Banda Aceh at 15% with better on-site systems built post the 2005 Tsunami and in low permeable soils. These are mean figures and hide the reality that some pits had never been emptied while others had been emptied at regular intervals, however highlights that basing designs on 100% of population emptying is an over-estimate. Data from the household surveys found 59% of systems had never been emptied after an average 15 years operation. The actual proportion of systems which have never been emptied will be higher, because systems with pit access were preferentially sampled for sludge measurements, which are more likely to be those that had previously been emptied.

The first emptying occurred after an average 16 years, but the second empty was required after only 2.4 years. At first emptying the systems had a sludge depth of 45% compared with only 17% in regularly emptied systems. The much shorter period before second emptying and demand for emptying despite low sludge accumulation would be consistent with poorer percolation possibly due to percolation paths becoming clogged after many years operation.

The main reasons for pit emptying given by interviewees were: the toilet not flushing (45%), blockage of the pipe between toilet and pit (15%), followed by preventative emptying, unpleasant smells, overflowing tanks/pits and household renovations. In some cities the emptying request took over three days to complete which caused embarrassment to some respondents as they had to use neighbours toilets. In the cities assessed, vacuum trucks with grinder pumps were the main emptying method. Most were operated by government authorities with private service providers also operating in three of the cities. Small motorbike tankers had been purchased in two cities and at the trial project in West Jakarta but had not been used more than once due to their small size, the lack of transfer stations and the lack of demand for emptying from very dense areas. Trucks with at least 3m3 storage, strong pumps and long hoses would be a more suitable option for systems that are hard to access.

Sludge accumulation

The sludge accumulation rates were calculated by multiplying the thickened bottom sludge depth by the internal pit dimensions, and divided by the average number of users and the years since last emptied as provided by homeowner.

In Indonesia sludge accumulation rates are on the low end of previous international studies, consistent with the climatic conditions, toilet use behaviour and local latrine construction practices. The mean rate of sludge accumulation is 25 litres per person per year (l/p.y) but the median value of 13 l/p.y is important because the mean is influenced by the very high rates in some regularly emptied systems, see Figure 2.

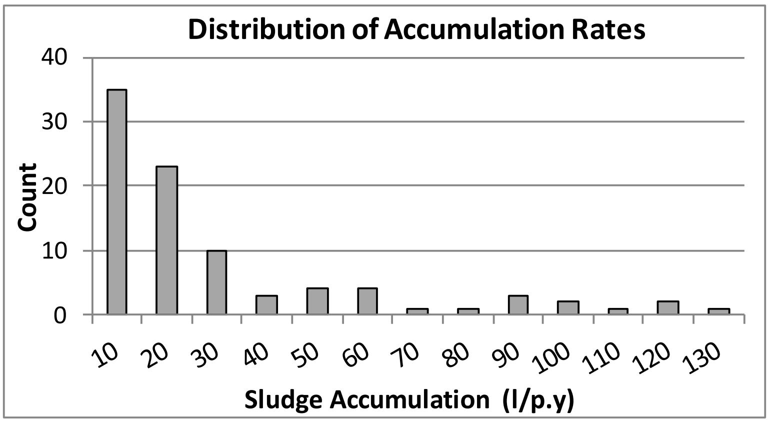

Figure 2. Sludge accumulation distribution

There is a significant decrease in accumulation rates over time as shown in Figure 3. This was also found in previous studies, and is possibly due to a delayed digestion start-up due to the practice of complete removal of sludge. [iii] Some guidelines recommend leaving some digested sludge in a tank to seed digestion, this was not observed in any sludge removal in Indonesia and is an option to improve treatment and possibly delay subsequent emptying. [iv]

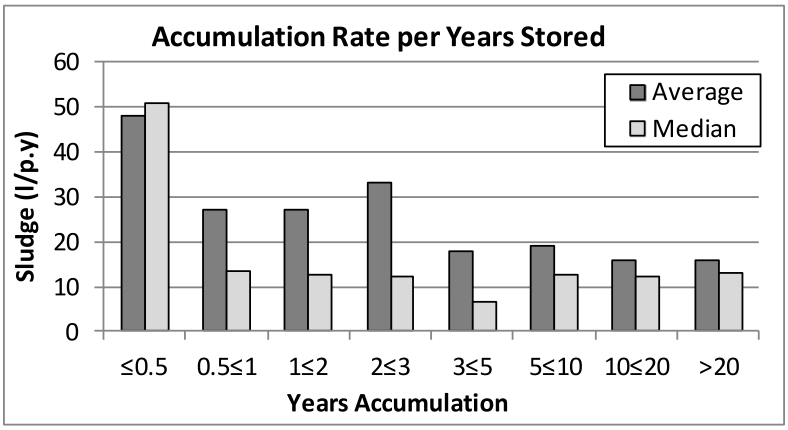

Figure 3. Reduction of sludge accumulation with years

Never emptied systems had a lower sludge accumulation rate at 14 l/p.y compared with regularly emptied systems at 41 l/p.y, which accords with the above point, since and never emptied systems were an average 15 years old and regular emptying occurs after less than 2 years storage.

Accumulation rates increase with system volume with systems smaller than 0.75m^3, such as those installed by development partner organizations in low income houses in West Jakarta or Belawan, having almost no settled sludge after more than 2 years use. These systems are an average 0.6m^3 compared with 2m^3 for all other systems investigated despite similar number of users. This causes high flow velocities and a short retention time, which may be insufficient to allow settlement so that solids are carried through the tank and discharged. However, a more detailed study is needed to confirm this. Similarly, systems with outlet pipes (to drains, river or soak pits) have an average accumulation rate of 15 l/p.y compared to 31 l/p.y for systems without an outlet, indicating that some solids are likely to be leaving through the outlet pipe.

The similar conditions prevailing across all sites with regard to temperature, toilet type and waste addition meant that the effects of these variables could not be individually but all are likely to influence the low rate of accumulation. Groundwater level, type of system, water use and income were analysed but no significant relationships were found between these parameters and sludge accumulation rates. The main influencing variables were number of years' accumulation, volume of system, presence of an overflow pipe and emptying frequency.

Sludge characteristics

The laboratory analysis of sludge samples was inconclusive on the typical sludge characteristics due to little experience in analysis of wastewater sludge. The design of treatment, selection of vacuum pump and the estimation of emptying time should cater for less stabilised and more liquid contents from regularly emptied systems to the well stabilised thick contents from older systems.

Recommendations

The results strongly indicate sludge accumulation is at the lower end of the rates suggested by previous studies, with an average of 25 l/p.y proposed as a design value for Indonesia. From the finding that the households requested that systems to be emptied when 1/2 full of sludge, this sludge depth could be used as a trigger for emptying. Based on average accumulation rates and volume, a typical system would be half full of sludge and require emptying after 8 years.

Consideration of number of systems emptied, itself dependent on demand for emptying, is important when planning sludge collection and treatment systems. Current treatment plant design assumes that all pits will be regularly emptied, resulting in operational problems at treatment plants due to gross under loading. Although programs exist to increase demand through improved awareness and management, it is recommended that designs are based on current emptying rates with modular designs to expand as required.

With low public awareness of the need to remove sludge from on-site systems, low accumulation rates and many large systems, it is not surprising most systems have never been emptied. However after first emptying, subsequent emptying can be required after a few years and these should be target customers for proposed regular desludging programs. An alternative option that requires further investigation, is to delay the time until the next emptying by leaving some sludge during removal to seed digestion in comparison to a delayed start up of sludge digestion processes in systems fully emptied.

The small systems constructed in dense low income areas of West Jakarta and Belawan are promoted as options to improve sanitation in very dense urban areas or in wet conditions, however with almost no sludge accumulation after over two years use, their design and performance should be investigated further.

The type of existing on-site system should be considered in sewerage design. . One of the main problems in many Indonesian cities is the lack of fall, which means that it is difficult to maintain self-cleansing velocities in conventional sewers. One response to this problems is to build interceptor tanks, or connect the discharge of existing septic tanks, and to design the sewer as a solids-free sewer, laid to much flatter gradients than a conventional sewer. If existing systems are used as inceptor tanks, it is important that they are sealed. Otherwise, continued leaching may continue to pollute groundwater and reduce or completely replace discharge to the sewer. In already-developed high density areas, complete separation of foul and storm water may be difficult. In Vietnam and the Philippines, interceptor sewers collect discharges from existing open drains and so deliver storm flows to sewers. This system is currently being considered for Jakarta. It assumes that wastewater is discharged to drains, either directly or via a septic tank. In practice, with only 22% of the sanitation facilities investigated having an overflow to a drain, interceptor sewerage in most areas would not capture and treat the blackwater. Therefore the existing quality and discharge of on-site systems must be assessed in selection of sewerage options.

Conclusion

Surveys of 190 households and assessment of 110 on-site sanitation systems across six cities in Indonesia revealed sludge accumulation rates at the lower end of the range recorded by previous studies and most systems had not been emptied. The study provides an indication of sludge accumulation rates and influencing variables for predominately unsealed on-site systems in a warm climate, with wet contents and minimal rubbish addition. Although limitations in access to systems biased the study to focus on systems previously emptied, there was sufficient data to assess the effect of other variables. The years of accumulation, volume, frequency of emptying and discharge were found to influence accumulation rates. With a very small proportion of on-site systems currently emptied, an appropriate estimate of demand should be determined for each city. Additionally, with most systems leaking from the base and not overflowing to drains, the benefits of regular emptying are reduced and improving containment should be a priority, particularly in areas dependent on shallow groundwater for water supply.

To improve on-site systems requires clarification of government responsibility, improved understanding of their function and increased awareness of the possible drawbacks of systems based on large single leach-pits. Users need to be aware that they cannot assume such systems will never need emptying and that relatively frequent emptying may be required after a pit first requires emptying. In recommending a type of on-site sanitation system, there are many technical, social and financial aspects that must be considered, as well as the varied environmental and health benefits specific to local conditions. In recognition that on-site sanitation will play an integral role in the future of Indonesia's wastewater management, improved understanding of these aspects by all stakeholders involved in on-site sanitation promotion and construction is necessary to improve this sector.

The research outlined in this paper has clarified the parameters to be used in designing sludge treatment systems and producing management and financing models. It highlights the typical quality on on-site systems in Indonesia is not well sealed standard septic tanks, instead most are single pit systems that leach liquid from an unsealed base. It is necessary to adopt realistic assumptions about sludge accumulation rates and the ways in which pit and tank configuration affects demand for pit emptying services when designing faecal sludge treatment plants. Failure to realistically assess accumulation rates and demand for pit and tank emptying services will lead to over-design and operational difficulties.

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References

BPS (2013) *Indonesia Demographic and Health Survey 2012*. Badan Pusat Stastik (BPS): Jakarta.

Franceys, R. P. (1992) A *Guide to the Development of On-site Sanitation.* WHO: Geneva.

Howard, T. (2003) *Solids Accumulation Rates for On-Site Sewage Treatment and Disposal Systems: A Focus on Charlotte County Florida.* University of Florida: Florida.

Moores, J. (2002) *Septic Tank Pumping Frequency Project.* Dalhousie University: Nova Scotia.

Norris, G. (2000) *Sludge Build-Up in Septic Tanks, Biological Digesters and Pit Latrines in South Africa*. Water Research Commission: South Africa.

Sasse, L. (1998) *DEWATS: Decentralised Wastewater Treatment in Developing Countries* BORDA: Delhi.

Still, D., & Foxon, K. (2012*) Tackling the Challenges of Full Pit Latrines.* Water Research Commission: South Africa.

World Bank (2013) *East Asia Pacific Region Urban Sanitation Review: Indonesia Country Study*. World Bank: Jakarta.

Notes

[i] Previous relevant studies in Canada (Moores 2002), USA (Howard 2003), Ethiopia (Sahle 1988 referred to in Norris 2000), and South Africa (Norris 2000) and (Still and Foxon 2012).

[ii] Ministry of Public Works Budget for Sanitation for 2014 (*Rekap Kegiatan Air Limbah APBN Seluruh Propinsi TA* 2014), program for sludge treatment plants in 18 cities worth Rp 118 billion, February 2014.

[iii] Higher accumulation rates or factors for the first year were found by Shale and Drews (in Norris 2000), and Weibel (in Howard 2003), becoming constant after 7-10 years. Bounds suggested microorganisms required up to 2 years to reach solid decomposition activity levels that are high enough to impact accumulation rates (ref in Howard 2003).

[iv] Sasse 1998 Chapter 9.2: Septic Tank "When removing the sludge, some immature (still active) sludge should be left inside to enable continuous decomposition of newly settling solids".

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