PIT EMPTYING SYSTEMS

Introduction

On site sanitation systems have been adopted throughout the developing world as a means of reaching sanitation coverage targets. A growing concern surrounds how these facilities can be effectively emptied. This becomes increasingly important in densely populated urban areas where the practice of covering a full latrine and relocating the superstructure is often not possible. Furthermore, access to latrines using large motorised vacuum tankers is becoming increasingly difficult; if these vehicles are even available at all. In rural areas relocating a latrine will often provide a safer and more financially viable solution than emptying it, especially in remote areas where mechanical equipment is not present.

This technical brief describes the main technology categories used for emptying on-site sanitation facilities, whilst highlighting their benefits and disadvantages. Prior to this description of technologies, a background is given into how emptying can be planned for during the inception phase of a sanitation project and a background into the wider issue of faecal sludge management (FSM).

Planning for Emptying of Sanitation Facilities

As with many technologies and practices, emptying is likely to depend greatly on the area where the latrine is located. This section will explain the affect sanitation facility type, groundwater conditions, filling rates and composition can have on the frequency and cost of emptying.

Prior to construction of sanitation facilities there are a number of considerations that can be made in an attempt to simplify the emptying process. One important note is that any spillage of excreta during emptying is likely to affect the health of not only workers, but also the nearby community as the pathogens contained within the excreta can be transmitted by flies (Franceys et al, 1992). Care must be taken at all stages whilst emptying to keep equipment and the surrounding area clean.

The constructed facility should always be located close to a household plot boundary, preferably close to the nearest access point. However, when citing a latrine/septic tank the facility should be located downwind of the property to prevent unpleasant odours in the household. If it is not possible to meet both criteria it is important to provide adequate access and ensure workers or hoses will not have to travel through the household.

Sanitation Facility Type

The different sanitation systems have been described in the technical brief 'Types of toilet and their suitability'. Of these, the only systems requiring emptying are those which fall into the on-site sanitation category e.g. pit latrines, pour flush latrines, septic tanks. Note that although ecological sanitation (ecosan) systems also requiring emptying, if the system has been operated correctly (refer to technical brief 'Ecological Sanitation: A Concept') then the waste can be removed with less caution as its lower pathogen content poses less of a health risk. Pit latrines are emptied when the sludge rises to within half a metre of the top of a latrine. Below are some important criteria to consider before selecting a sanitation type.

Pit Latrines – Encompassing VIP and simple pit latrines. Householders will save money in the long term if pit latrine slabs do not need to be dismantled to allow emptying. Manual emptying is likely to require better access then mechanical emptying as a person may need to climb inside. It is possible for the slab to contain removable segments (if used these should be well sealed to prevent flies), or simply allow it to be lifted completely off when emptying is required. Similarly the superstructure of the latrine must facilitate access, by easy removal or pit access provided outside the superstructure. The dry and thick nature of waste in pit latrines (unless pits are lined (see below)) can make removal difficult and put strain on mechanical pumps. Some users may also prefer to use solid anal cleansing materials which could block emptying equipment and cause faster sludge accumulation.

Pour Flush Latrines and Offset Pits – The inclusion of water will increase sludge liquidity and make emptying slightly easier. The water seal prevents the use of solid anal cleansing material and thus protects emptying machines. However, the water seal also prevents direct emptying, thus some form of separate access to the pit must be supplied. Water seals have sometimes been smashed in order to gain access, negating their advantages. Many pour-flush latrines have offset pits which are advantageous as access can be easier (as long as the pit is located in an accessible area).

Unlined vs Lined Pits – The decision to line pits or not is discussed in the technical brief 'Types of Toilet and Their Suitability'. When planning for emptying systems lined pits are likely to hold more water and make sludge easier to remove. Unlined pits constructed in unstable ground are likely to collapse when emptied, posing a risk to manual workers.

Septic Tanks – Septic tanks should be inspected periodically to ascertain if emptying is required. They should not be emptied when full, but when the solids component of the waste fills between one half and two thirds of the tank. If the tanks are allowed to fill with solids then the retention time of the tank will not be long enough and the effluent will contain unacceptable levels of pathogens. Furthermore, septic tanks should not be completely emptied, and a small amount of digesting sludge should be kept in the bottom (Franceys et al, 1992).

It is also important to plan for the costs incurred after construction. If householders are able to afford a latrine, are they able to fund the recurring emptying costs and what are these costs likely to be. It would also be ideal during the planning of a project to ascertain what emptying systems are available and discuss and advise customers of their options and corresponding costs at the time of construction.

Ground Conditions

It is also possible for the ground conditions to affect emptying. Groundwater could have an affect on liquidity with dry conditions making sludge harder to pump and wet conditions making emptying the liquefied sludge easier. The local drainage conditions will also affect the liquidity, if flooding occurs emptiers are likely to wait for flood waters to assist with sludge removal. The permeability of the ground can also affect the liquidity, with more permeable soils resulting in drier waste and impermeable ground resulting in a wetter pit due to seepage restriction.

Filling Rates and Composition

The rate at which pits fill and the composition of the waste can vary drastically between households. Further research into these topics is required, but controlling the factors is extremely problematic. Some households may dispose of household waste into the latrine which could vary the filling rate and adjust the regularity with which services should be provided. Furthermore, the inclusion of greywater and solid anal cleansing materials can cause greater variance. Table 1 shows estimated accumulation rates.

Table 1: Suggested maximum sludge accumulation rates (litres/person/year) [Source: Franceys et al, 1992]

	Accumulation rate
Wastes retained in water; degradable anal cleansing material used	40
Wastes retained in water; non-degradable anal cleaning materials used	60
Waste retained in dry conditions; degradable anal cleaning materials used	60
Wastes retained in dry conditions; non degradable anal cleaning materials used	90

Note: 'in water' means the groundwater level is above the top of the sludge

It is widely accepted that filling rates vary and that they should be estimated for the area under consideration. Accumulation rates from different research locations compiled by Still (2002) show rates varying between 18 and 70 litres/person/year (l/p/y). There are no standardised rules and Harvey (2007) suggests even higher rates for emergencies, with 0.5 litres/person/day (l/p/d) (182.5 l/p/y) for solids and 0.8 l/p/d (292 l/p/y) for urine accumulation (increasing to 1.3 l/p/d (474.5 l/p/y) if water is used for anal cleansing). If possible estimates of local rates should be used; otherwise the figures in table 1 provide a suitable estimate.

The equation in box 1 was adopted by Harvey et al (2002) to calculate latrine volume. This equation helps with the design of new pit latrines, whereas the equation in box 2 shows how to calculate the duration between emptying operations for an existing latrine.

Box 1 – Equation for volume of pit

$$\text{Volume of Pit, } V = \frac{(N \times S \times D) + 0.5A}{1000}$$

Box 2 – Equation for emptying frequency

$$\text{Design Life, } D = \frac{(V - 0.5A) \times 1000}{(N \times S)}$$

Where V = volume of pit (m^3); N = number of users; D = design life (years); S = sludge accumulation rate (litres/person/year); and A = pit base area (m^2).

As an example, if a household of 8 people were using one latrine, with a pit base area of $1.5m^2$, the conditions were dry, and stones were used for anal cleansing. From table 1 a sludge accumulation rate of 60 l/p/y would be selected. If it is known that the volume of the latrine is $4m^3$, then the emptying period (design life) can be derived from the equation in box 2. Using these values the design life is found to be 6.8 years.

There are still many knowledge gaps in this area. For example, accumulation rates do not specifically take into account soil infiltration rates, which will affect the extent to which urine and water contributes to the accumulation volume. Furthermore, it is accepted that once a large volume pit has filled once it will not be completely emptied (due to gradual compaction of sludge), reducing its effective volume and the subsequent design life. Wherever possible local information should be sought on what filling rates people observe and these values should be assessed against calculations.

Introduction of solid anal cleansing materials (such as corn cobs and textiles) into latrines can potentially block or damage emptying equipment. Prior to introducing an emptying technology, establishing with users what material is likely to be in pits could mitigate risks.

Institutional Environment

To ensure the safe transfer of excreta from a household level to adequate disposal and treatment a variety of stakeholders are likely to be involved. If implementing collection systems alone it would be advisable to assess how excreta will be transferred to an end disposal point. In some cases municipalities may assist with moving the waste on from some form of collection point, if this is the case responsibilities should be clear.

There should also be consideration for national regulations and what requirements these put on emptying services. In the absence of such regulation an appreciation of the entire faecal sludge management chain would bring significant benefits to environmental health.

Faecal Sludge Management

The term given to the management of waste through collection, haulage, disposal and treatment is faecal sludge management (FSM). Figure 1 shows the chain with examples of possible activities at each stage.

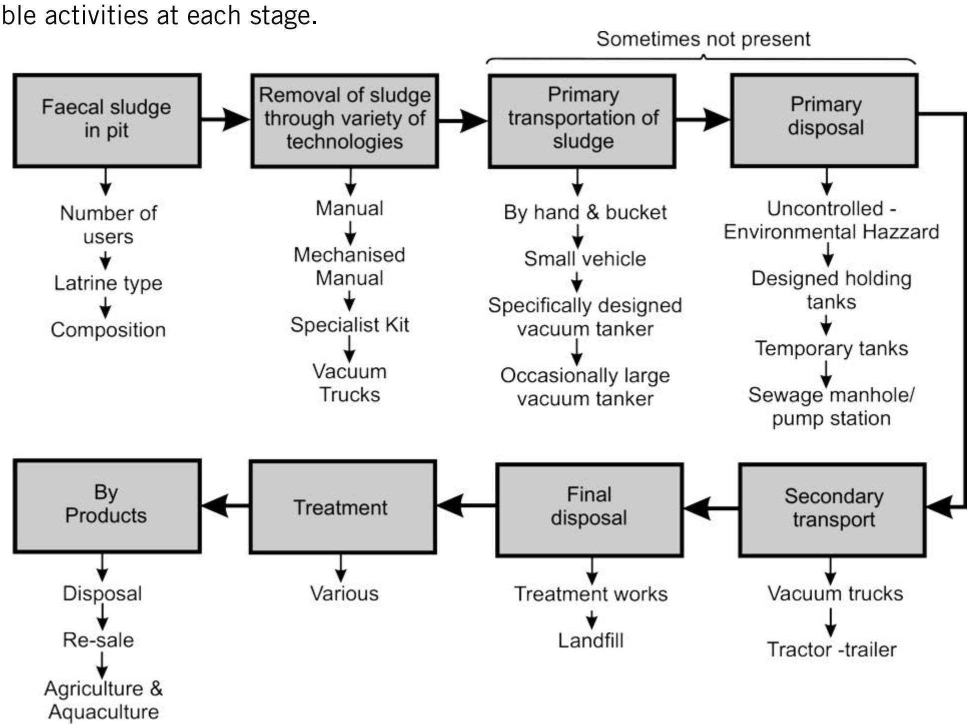

Figure 1: The FSM process, from generation to by-products [Illustrator: Niall Boot 2007]

An appreciation of the full FSM process can result in successful achievement of the core goals i.e. preventing excreta from entering the urban environment and being used inappropriately in agriculture. Although this technical brief discusses possibilities for emptying it cannot be emphasised enough that it should not be tackled in isolation. For example, if one vacuum tanker indiscriminately dumps faecal sludge into the environment it is comparable to 5,000 people defecating openly (Strauss et al, 2006); effectively negating the very purpose of on-site sanitation systems. A number of recent studies have identified haulage distances as a possible area for reducing overall expenditure on FSM services (Strauss and Montangero, 2002).

Demand Responsive Services

Many emptying systems have become demand responsive whereby customers are requesting their facility to be emptied. The service provider will then travel from a previous household (or a disposal point) to the requested place, resulting in very disaggregated demand. This generally means that the services are more costly, partially as a result of treatment plants (or disposal points) being centralised and the large transport distances involved. Some attempts have been made in the past to aggregates this demand by serving customer living close to one another.

Organising customers into clusters to be serviced on a regular basis (and possibly for a set fee) may reduce overall emptying costs. However, the benefits brought would be dependent on (i) the distance to a safe disposal point and (ii) the volume of faecal sludge being removed per visit i.e. if the volume exceeds one tanker then organising customers near to one another may be less beneficial.

technical brief

Emptying Methodologies

It is generally accepted that a pit should be emptied when the sludge is half a metre from the top of the pit. Compaction of sludge at depth may result in a need to add water in order to liquefy the sludge. The methods used to empty pit latrines can be categorised into four main groups; manual, manually driven mechanical systems, specifically designed mechanical systems and large vacuum tankers. Each of these categories will now be described in turn.

Manual Methods

Figure 2: Manual emptiers operating in Kibera, Nairobi [Photo Credit: WSP/Sabine Bongi 2005]

In many urban areas of the world manual emptying methods dominate the sector. Manual emptying occurs most frequently where large vacuum tankers are unable to access sanitation facilities. It is also generally the cheapest way of removing enough waste to keep a pit operational, although it is usually the most expensive per unit volume.

There are numerous types of manual emptying. Often it entails two workers using a rope and bucket (figure 2), if the waste becomes too solidified at the bottom of the pit a worker will have to climb in to remove the waste by hand. Sometimes pits will be emptied using gravitational emptying, whereby a hole is made in the side of the pit and excreta flow out under gravity (either into a nearby stream or an adjacent hole). In some cases residents allow flood waters to carry away the top level of sludge making it functional for a short period of time.

Often manual emptying causes environmental pollution because there is no safe place (such as a transfer station) for workers to dispose of waste. In some areas (such as Nairobi, Kenya) workers suffer from a significant stigma that forces them to operate at night. This not only increases the likelihood of worker injury, but also increases spillage. The stigma originates from a community dislike of the odour and spillage resulting from the work. Workers health could be affected by direct contact with faeces containing dangerous pathogens and gas build up in latrines.

If there is no other realistic option than to empty manually it is important to remember that fresh excreta will contain pathogens that could cause worms or diarrhoea. Furthermore, flies attracted to this may spread such diseases to local communities. It is important that no one should enter the pit without a safety rope and colleagues on the surface with the ability to pull the worker out. The risk of fumes and pit collapse are the two primary drivers for this. Workers should be provided with safety clothes and nearby washing facilities. Furthermore, pits should be adequately ventilated when a worker is inside (Scott and Reed, 2006).

Table 2: Advantages and Disadvantages of Manual Emptying

Advantages	Disadvantages
Services accessible to community	High unit cost of removal
Relatively cheap to keep latrine operational	Significant health risks to workers
Low equipment capital cost	Rarely acceptable to municipalities and so not regulated
	Associated with indiscriminate dumping
	Lack of appropriate equipment means spillage regularly occurs
	Will often require the slab of the latrine to be demolished to facilitate access, subsequently increasing householder cost

Manually Driven Mechanical Systems

The main technology type in this category is called the Manual Pit Emptying Technology (MAPET), it was developed in the early 1990s and came at a cost of US$3,000. The machine brought some successes but ultimately failed due to a reliance on imported spare parts and a lack of institutional support. Therefore it will not be discussed in further detail because it is unavailable for use.

A relatively new technology type in this category is the London School of Hygiene and Tropical Medicine (LSHTM) Sludge Gulper. This is a hand pump that can be lowered into a pit or tank and used to lift the contents out into a bucket. The system is currently still being trialled on varying types of sludge. Whether it performs successfully in all locations is yet to be seen.

There are two critical features of the sludge gulper which make it advantageous. Firstly it has been constructed entirely from local materials in Indonesia and Cambodia; one factor that brought about the downfall of the MAPET. Secondly the cost of the system is very low, costing only US$40 to build in Indonesia.

The two biggest potential problems are the non-odourless nature of the technology and the requirement for the further containerisation of the sludge.

Table 3: Advantages and Disadvantages of the LSHTM sludge gulper

Advantages	Disadvantages
Low cost when compared to other technologies, so suitable for small scale independent providers (SSIPs)	Requirement for further containerisation and safe disposal of waste
Possible to produce locally in many areas	Could still produce unpleasant odours
Facilitates access into even very densely populated areas	May be difficult to operate on thick sludge or low volume installation
Low operation and maintenance costs	

Specifically Designed Mechanical Systems

During the 1990s there have been a series of machines designed specifically for densely populated urban areas where access poses a problem. The most accessible of these technologies is the UN-HABITAT/Manus Coffey and Associates Ltd developed Vacutug machine (figure 3). Other technologies have been used, but they are less directly available; they include (i) the Manquineta (WaterAid/MSF machine) used in Mozambique, and (ii) Vacutug Mk II (figure 4), trialled in Dhaka, Bangladesh.

Figure 3: UN-HABITAT Vacutug.
Photo Credit: UN-HABITAT, n.d.

Figure 4: Vacutug Mk II mother tank.
Photo Credit: GHK, 2005

The Vacutug project is still awaiting the scaling up phase. Currently a number of machines are on trial throughout the world, and governments are being encouraged to take the lead on purchasing. The machine has a capacity of 500 litres, has a maximum speed of 5 km/hour, and comes at an approximate cost of US$5,000 – 7,000 (dependent on shipping costs). It can be difficult to completely empty deep pits, partially due to pit depth and partially due to sludge compaction.

One significant problem with the Vacutug Mk I is the low speed and the need for a localised disposal point. This was one driver behind the development of the Vacutug Mk II which uses a small satellite tank (200 litres) and a larger mother tank (1,900 litre) towed by a vehicle to take large volumes to disposal.

Table 4: Advantages and Disadvantages of the Vacutug

Advantages	Disadvantages
Removes waste safely for both workers and public health	Slow max speed means localized emptying point such as sewer or tank are needed
It is a low odour technology	Costs too much for many SSIPs
Faster to empty than either manual or manually driven mechanical systems	Is having some access problems in Kibera, Nairobi, despite its small size
Reduces social stigma on workers	Maintenance costs are potentially high

Some of the disadvantages listed above have been overcome with the development of the Vacutug Mk II. However, this increases costs due to the necessity to purchase a vehicle to tow the mother tank. More up-to-date information on the Vacutug systems can be acquired from UN-HABITAT (http://www.unhabitat.org/categories.asp?catid=548).

Large Vacuum Tankers

Large vacuum tankers (figure 5) are very widely used for emptying of sanitation facilities throughout the world. They are generally the most economic means (apart from sewerage systems) of moving large volumes of excreta. Their volume can vary between 5 and 10 m^3. It is generally agreed that they can operate effectively up to about 60m from an installation (although connecting and disconnecting these sections can be a time consuming process), and to a depth of 2 to 3 m. The large capacity means that to empty a pit to its practical limit may only take one or two visits. (Note: despite strong pumps a pit can often not be emptied completely due to sludge compaction and pit depth).

The two predominant problems facing such trucks are cost (both capital and maintenance) and, in urban areas, access to facilities. The machine cost will vary between locations, but a value exceeding US$100,000 should be expected. The ability to afford and access spare parts locally will also vary between locations, but if the technology is not widely used there is the likelihood of having to import spare parts.

Figure 5: A vacuum tanker discharges its load in Accra, Ghana. Photo Credit: Niall Boot, 2007

The use of such technologies has exhibited a low cost to customers, but only when considered on a unit cost basis. Due to the speed with which a tanker can exhaust a pit, despite its higher cost, it often costs less per m^3 removed. However, some households would still prefer to pay a small amount for a small volume removed as this is what local monetary conditions permit. There should be adequate planning to assess people's willingness to pay, both in quantity and regularity.

Table 5 – Advantages and Disadvantages of Vacuum Tankers

Advantages	Disadvantages
Removes waste safely for both workers and public health	Haulage distances are likely to be key in overall expenditure
It is a low odour technology	Costs too much for many SSIPs
Fastest means with which excreta can be exhausted	Access problems in many areas
Relatively fast travelling speeds has better possibility of economical disposal of waste	Maintenance costs are also high due to imported technology
	Despite being 'high technology' it does not overcome the lack of a disposal site

Tractor Trailer Units (Towing)

One method often cited as a means of reducing the overall cost of machinery is to have a towed unit that contains a form of pump. This potentially can save a lot of money on the capital cost, as such a system is likely to be cheaper than a large vacuum tanker. It is also likely to overcome the problems of containerisation facing some technologies and will facilitate haulage of waste at reasonable economic scale.

Submersible Pumps

It is generally accepted that vacuum pumps (whereby a vacuum is created in a tank which results in the waste being sucked into it) are the most appropriate systems for emptying pits. An alternative is a pump that is submersed within the pit and allows fluid to pass through it before pumping it upwards. The problem with such pumps is the ease with which solids can damage them. Despites this, in some areas the pumps have proven reasonably successful, however they should not be used where solid anal cleansing materials are used. Furthermore, the process requires containerisation and separate transportation.

Conclusion

This technical information is intended as a background to the possible options available for emptying an on-site sanitation facility. It also describes some of the more important wider issues such as the need for the correct institutions and an acknowledgement of the entire FSM chain.

The importance of cost is crucial when selecting a technology, as is the distinction between the requirements in a rural area and an urban area. Careful planning at the sanitation facility inception phase can reduce problems when emptying is later needed. If facilities already exist then talking to communities may enable the best form of technology to be adopted. Emptying of pits is a growing problem, to which limited resources have been granted. Solutions are only partial, but good planning can mitigate many risks. Finally, this brief has only taken into account emptying, it is critical that once faecal sludge is removed it is disposed of safely.

References and Further Reading

- *Sanitation Partnership Series: Bringing Pit Emptying Out of the Darkness: A Comparison of Approaches on Durban, South Africa and Kibera, Kenya.* Eales, Kathy (2005) Building Partnerships for Development (BPD).
- *A Guide to the Development of On-site Sanitation.* Franceys, R., Pickford, J. and Reed, R. (1992), World Health organisation (WHO), Geneva.
- *Decentralised domestic wastewater and faecal sludge management in Bangladesh*. GHK (2005) GHK Consulting Ltd, UK.
- *Emergency Sanitation: Assessment and programme design*. Harvey, Peter, Baghri, Sohrab and Reed, Bob (2002), Water, Engineering and Development Centre (WEDC), Loughborough University, UK.
- *Excreta Disposal in Emergencies: A Field Manual.* Harvey, Peter (2007), Water Engineering and Development Centre (WEDC), Loughborough University, UK.
- *Faecal Sludge Management in Developing Countries – A Planning Manual. 1st Edition.* Klingel, Florian, Montangero, Agnes, Kone, Doulaye and Strauss, Martin (2002)Department of Water and Sanitation in Developing Countries (SANDEC), Switzerland.
- *Technical Note 54: Emptying Pit Latrines.* Pickford, J and Shaw, R (n.d.)Water, Engineering and Development Centre (WEDC), Loughborough University, UK.
- *Sanitation Partnerships: Beyond Storage: On-site sanitation as an urban system*. Schaub-Jones, David (2005), Building Partnerships for Development, UK.
- *WELL factsheet: Emptying Pit Latrines.* Scott, Rebecca and Reed, Brian (2006)WELL, Loughborough University, UK.
- *After the Pit is Full….What Then? Effective Options for Pit Latrine Management*. Still, D.A. (2002) Water Institute of Southern Africa, Biennial conference, 2002. Durban, South Africa.
- *Faecal Sludge Management - Review of Practices, Problems And Initiatives (GHK DFID KAR R8056: Capacity Building For Effective Decentralised Wastewater Management).* Strauss, Martin and Montangero, Agnes (2002) SANDEC, Switzerland.
- *Proceedings of the 1st international symposium and workshop on faecal sludge management (FSM) policy: Dakar, 9-12 May 2006.* Strauss, Martin, Kone, Doulaye, and Saywell, Darren (2006) IWA, ONAS and SANDEC.
- *Sanitation – Vacutug.* UN-HABITAT (n.d.) UN-HABITAT Website.

Practical Action Technical Briefs
Waste Management
Sanitation Technologies

Practical Action Publishing titles on Sanitation

technical brief

This Technical Brief was written by Niall Boot for Practical Action in November 2007.

Practical Action
The Schumacher Centre
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/

Practical Action is a development charity with a difference. We know the simplest ideas can have the most profound, life-changing effect on poor people across the world. For over 40 years, we have been working closely with some of the world's poorest people - using simple technology to fight poverty and transform their lives for the better. We currently work in 15 countries in Africa, South Asia and Latin America.

techical brief