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Pit Latrine Emptying: Technologies, Challenges and Solutions

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Abstract

Millions of households rely on pit latrines for sanitation and when a pit fills up, emptying is often the only viable option. Despite the development of several technologies, their limitations have underlined the need for further improvements. Creating a solution that is able to access densely populated settlements, efficiently empty dense sludge and dispose of them at an appropriate location, while remaining affordable and easy to operate and maintain is a difficult task. This paper reviews and evaluates the recent technologies that have been developed and outlines the main challenges that must be addressed in today's context.

1. Introduction

The United Nations Millennium Development Goals aim to improve sanitation by halving the proportion of people without an improved sanitation facility[1]. Many developing countries are working toward those targets, however, in order to sustain what has been achieved this must take into account the need for septic tanks and pit latrines to remain in useful working condition. Part of this need involves emptying septic tanks and latrines when they fill up so that they can continue to function and contribute to health and environmental outcomes. Unfortunately, there are many technical challenges in trying to do so, especially in today's context of increasing population density, lack of technological options and meagre resources available to local authorities.

2. When the pit fills

A person should stop using a pit latrine when it is almost full. There are two options: one, stop using the latrine and construct a new one or; two, empty the contents and reuse it (Pickford and Shaw, 1997). Often, the lack of available space or costs of constructing a new latrine superstructure and pit means that pit emptying may be the only practical alternative (Muller and Rijnsburger, 1994).

Neglecting pit emptying requirements can have serious health and environment consequences. For example, substandard pit emptying services in Freetown, Sierra Leone, have partly caused diarrhoeal disease, cholera outbreaks and high infant mortality, especially in slums and poor,

[1] Improved sanitation facilities are: connection to a public sewer, connection to a septic system, pour-flush latrine, simple pit latrine, ventilated improved pit latrine.

unplanned areas (Parkinson, 2008). If the users continue to use the pit when it is full, the excreta will overflow and the risk of oral-faecal intake will increase. Thus the overall benefits of improved sanitation will reduce substantially.

3. Technologies

The conventional method for pit emptying is the **vacuum tanker**. This is a truck-mounted tank between 1 to 10 m^3 in capacity with a vacuum pump connected to the tank to suck out the sludge commonly used in industrialised countries. However, there are technical limitations to the use of the vacuum tanker in areas with inadequate road access, shortage of spare parts and fuel.

On the other end of the technological scale, **manual emptying** is common in many areas worldwide such as sub-Saharan Africa (WUP, 2003). Manual emptying generally involves accessing the pit, which in some cases done by destroying the squatting slab and digging the sludge out with simple hand tools such as spades, shovels and buckets by a team of workers, sometimes borrowed or rented from the customer. If the sludge is liquid, buckets and rope may be used to scoop the sludge out (Eales, 2005). This method is usually discouraged, however, mainly due to the pathogenic nature of the sludge and the undesirable nature of the work. Then there are also issues of final disposal of faecal sludge. In Kibera, Nairobi, manual emptiers are subject to violence and extortion (ibid); the practice is illegal in Dhaka, Bangladesh (Parkinson and Quader, 2008). Despite this, it is still one of the most common practices of emptying pits.

In between these two ends of the spectrum there are: mini-vacuum tankers, essentially scaled-down versions of the vacuum tanker such as the UN-HABITAT Vacutug, and; manual pumps such as the Manual Pit Emptying Technology (MAPET) and Manual Desludging Hand Pump (MDHP).

The **UN-Habitat** has been supporting a number of pilot projects and their **Vacutug MK II** has a trailer-mounted 1,900-litre tank used in conjunction with a 200-litre satellite tank attached to a vacuum pump (Parkinson and Quader, 2008). Trials for it were started in Kenya, Bangladesh, Senegal, Tanzania, India, Mozambique, South Africa and Ghana in 2003 (Alabaster, 2008). The pilot project in Dhaka has successfully improved emptying services to poor, congested slums but there are concerns about its commercial viability. The improvement and experimentation of the Vacutug by UN-Habitat is still continuing in Eastern Africa (Coffey, 2009)

The **Manual Pit Emptying Technology (MAPET)** was developed in Dar es Salaam, Tanzania in the 1980s by WASTE Consultants together with the Dar es Salaam Sewerage and Sanitation Department. The two core elements of the MAPET are the piston pump with the flywheel and the 200-litre vacuum tank. Each is mounted on a push cart (Muller and Rijnsburger, 1994). The pilot project was initially successful but the lack of institutional support and difficult in obtaining components have led the MAPET to no longer be used there (BPD, 2008). In this project, the technological elements of machines were combined with social and economic aspects, such as income generation, enterprise development etc.

The **Manual Desludging Hand Pump (MDHP)** (Figure 1) was developed by the London School of Hygiene and Tropical Medicine together with Oxfam in Indonesia. Apart from the MDHP, other equipment stipulated by Oxfam (2008) includes one bucket (minimum 50 litres), fibre bags if possible, a hoe and shovel and protective equipment.

Figure 1 The MDHP [Oxfam (2008)]

The Vacutug, MAPET and MDHP have all been promising technologies in one way or another although none have been proven on a large scale. The table below provides a comparison of the advantages and disadvantages of different methods of emptying.

Table 1 Advantages and disadvantages of various methods of pit emptying (Boot, 200

Vacuum tankers	
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
The Vacutug	
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 small scale independent providers (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
Manual Desludging Hand Pump	
Low cost when compared to other technologies, so suitable for 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	
Manual emptying	
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

4. Challenges

In order to develop a technology and to ensure its use, there are many design criteria that should be fulfilled. Below, some of the more important criteria are described.

Access

Access is one of the main reasons why manual emptying is so common. Large vacuum tankers are simply unable to traverse the narrow streets in unplanned settlements. Although longer hoses can be used, the maximum length possible is approximately 50 m (Still, 2002) and adds to the cost of emptying. Even the Vacutug, designed with accessibility in mind, is unable to access some of the narrower paths in Dhaka, Bangladesh (Parkinson and Quader, 2008). The MAPET has a small width of 800 mm, but there was difficulty in navigating the poor roads due to its tyres. On the other hand, at 2 kg in weight and approximately 2 m in height (Oxfam, 2008), the MDHP appears extremely portable and easily moved around.

Effectively emptying pit contents

Vacuum-based technologies have experienced difficulties with various kinds of sludge. Vacuum pumps are unable to deal satisfactorily with dry sludge or solid objects like stones, sticks and other rubbish (Harvey, 2007). This is because the vacuum system depends on the material pumped behaving as a fluid (Hawkins, 1982). Thus density of sludge is an important criteria, though often water is added before emptying starts. Water is often short in supply in low income areas.

The technologies are only able to empty to a limited depth. A vacuum tanker can lift a depth of up to 2 to 3 m (Pickford and Shaw, 1997); the Vacutug cannot empty pits more than 2 m deep (Parkinson and Quader, 2008); the MAPET has a maximum pumping head of 3 m (Muller and Rijnsburger, 1994); the MDHP only reaches 80 cm down the pit (Oxfam, n.d.). This also depends on the density of sludge. The higher the density of sludge, the greater the static head required of a vacuum-based emptying technology. Observations have measured the density to range between 0.97 kg/dm^3 to 1.75 kg/dm^3, which would require an unobtainable static head of 12 m (Hawkins, 1982). Other importance considerations are that pit depths can vary widely, there may be no need to empty the pit completely for it to function acceptably, and it may be unaffordable for users to empty more than a limited amount of sludge at a time.

Operation and maintenance

Operational and maintenance is crucial to the sustainability of the pit emptying technology, in particular, the affordability and availability of spare parts, power source and regular servicing. There are many cases of pit emptying machines failing or deteriorating due to the inability of the users to find replacement parts. Vacuum tankers are a classic example in this respect because of the high reliance on imported fuel and spare parts. Building Partnerships for Development (BPD, 2008) cited the foreign component as part of the reason why MAPET, even though it was locally manufactured, is no longer being used in Dar es Salaam. When the foreign part broke down, it could not be replaced or substituted by local parts.

Cost

Proposed business models, for example in Freetown (Parkinson, 2008) and eThekwini (Eales, 2005), often have small private sector enterprises providing small-scale emptying services and the local authorities responsible for conventional vacuum tanker services and larger scale infrastructure such as transfer stations. Provision of transfer stations and their reliable operation is necessary for the success of small scale enterprises. There is increasing acknowledgment of the role small-scale enterprises can play in the pit emptying market (Bongi and Morel, 2005; Scott, 2006), though lessons learnt from solid waste management suggests that municipal governments often fail to provide such systems (Ali, 2009) (Put it under reference personal communication by Mansoor Ali)

To facilitate the entry of small-scale enterprises into the market, the cost of pit emptying must be affordable and the external environment must be supportive. Besides the capital cost, there are the long-term operating costs, such as fuel, permits, haulage, disposal, cleaning, spare parts and maintenance (Eales, 2005; LSHTM/WEDC, 1998). This is an area where engineers and business specialist must learn to work together.

Table 2 Comparison of the capital costs of pit emptying technologies

Pit emptying technology	Cost per unit of equipment	Source
Vacuum tanker	US $ 50,000 to 80,000	Klingel et al (2002)
Vacutug MK II	US $ 4,400 - 5,100*	Issaias (2006); Parkinson and Quader (2008)
MAPET	US $ 3,000	Muller and Rijnsburger (1994)
MDHP	US $ 40*	Boot (2008)
Manual emptying	US $ 39 – 104 US $ 130	Bongi and Morel (2005) Eales (2005)

*excludes ancillary equipment such as towing vehicles, protective gear etc.

It is common for conventional vacuum tanker services to be subsidised by the local authorities and serving accessible planned areas. Councils in South Africa typically absorb 80% to 90% of the costs (Still, 2002). Eales (2005) suggests that the high subsidy gives little incentive for competing technologies to enter the market. However there are many areas vacuum tankers cannot access which smaller scale technologies have the potential to service.

Strauss and Montangero (2002) point out that while external agencies often partially or fully fund the initial capital costs, the operation and maintenance cost is beyond the capacity of local organisations. Parkinson and Quader (2008) also indicate that the revenue from the Vacutug pit emptying service in Dhaka is only able to cover the staff salary but not the operation, maintenance, garage rent, capital and depreciation costs. (Note the cost in Table 2 does not include the cost of the towing vehicle which was bought at US $ 7,500).

Disposal

Once the sludge is collected it has to be disposed of. Therefore disposal must be considered in parallel with pit emptying technologies. Final disposal of solid wastes, including sludge, is one of the most neglected infrastructure in developing countries . The provision of inadequate facilities may result in indiscriminate or illegal disposal of sludge to rivers, open drains, the sea or any open space (WUP, 2003), particularly if the emptying technology does not possess appropriate haulage capacity for long distances and government systems are not supportive.

Time spent transporting the sludge to the disposal site consumes time that an expensive vacuum pump could be emptying a pit. A previous study indicated that in Dar es Salaam where there was no transfer system, vacuum tankers spent 60% of the time travelling (Hawkins, 1982). This may result in a large increase in costs (Franceys et al, 1992).

Disposal of sludge close to the latrine is considered the most economic method (Still, 2002). This involves digging a latrine, filling it up with sludge, letting the liquid leach out of the sludge for one or two days, then covering it with at least 30 cm of dry, excavated soil (Muller & Rijnsburger, 1994). This is common in low- to medium-density areas (WUP, 2003), but is increasingly limited by the space available and the depth of the groundwater table, as groundwater may be contaminated (Muller & Rijnsburger, 1994). Other options include transporting it directly to the sewerage network or an intermediate point to be transported further.

The main limitation in disposing the sludge is that disposal sites tend to be too far for most pit emptying technologies, besides large vacuum tankers, to reach. Still (2002) states that the MAPET and Vacutug is an impractical solution if the disposal site is more than 1 km away. This is in part due to their slow road speeds: the MAPET is self-propelled (Muller and Rijnsburger, 1994), and; the Vacutug has a road speed of only 5 km/h (Parkinson and Quader, 2008).

Other possible issues to consider include: the capacity of the site to accommodate the sludge (Chaggu et al, 2002), acceptability of the site to neighbouring residents (Klingel et al, 2002), disposal fees (ibid) etc.

5. Solutions

Based on the above discussion this paper suggests five key design parameters of an appropriate pit emptying technology;

1. Ability to completely and effectively empty a pit with dry and liquid sludge, dense sludge and sludge with solids.
2. Ability to access densely populated areas with narrow streets and poor roads.
3. Easy and affordable to build, operate and maintain locally.
4. Allows small and private enterprises to be commercially viable, especially in low income areas.
5. Appropriate infrastructure to dispose of the sludge.

It is difficult to fulfill all the criteria and some may need further innovation, for example, zoning low and high income areas together. Expensive vacuum tankers are able to transport sludge directly to distant disposal sites, but the cheaper Vacutug, MAPET and MDHP require nearby areas. Klingel et al (2002) promotes the use of several decentralised disposal sites instead of a single central disposal site to overcome the problem. This seems to be the best way to facilitate the success of small-scale affordable technologies, but may require significant investment. Again, it conflicts creating cheap-to-operate service.

Perhaps the fundamental problem is the use of vacuum-based technologies, given that they are inherently unable to effectively deal with less liquid sludge. A solution around this would be to move away from vacuum-based technologies entirely or to modify its operation substantially, for example, by introducing air in the sludge to reduce its density. Innovations so far have been focused on scaling down the conventional vacuum tanker (Sugden, 2008), which might not be the optimum way to tackle the problem. A non vacuum-based technology is the continuous chain device recently developed by Sugden (2008) (Figure 2). It is manufactured out of local components and based on scooping action rather than vacuum action.

Figure 2 Continuous chain device [Sugden, 2008]

The concept of using additives to reduce the amount of sludge or rate of sludge accumulation has also been discussed. This would lead to less frequent emptying. However, trials have had variable results and further studies are required to determine its viability (Harvey, 2007).

6. Conclusion

The challenges in pit emptying are complex, compounded by the variable and often difficult conditions in which emptying technologies must operate. As more innovations are tested and improved, progress can be made towards a satisfactory solution. However, this will take time as some difficulties are not identified until technologies have been used for a sufficient period. There may also be scope to investigate novel ways of emptying pits instead of simply attempting to adapt current technologies. There is also a scope to draw lessons from research done in the management of municipal solid waste. This should always be carried out with a system of haulage and disposal in mind.

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