THE CHALLENGES OF DEALING WITH FULL VIP LATRINES

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Abstract

Fully waterborne sanitation is only practically and economically possible for homes located in towns and cities, and not even for all of those. In South Africa's drive to provide basic sanitation for all over two million VIPs and other on-site sanitation systems have been built since the early '90s, as many again are yet to be built, and sooner or later all on-site sanitation systems require emptying. This paper looks at the following questions: At what rate does faecal waste accumulate in on-site sanitation systems? What are Water Services Authorities in South Africa doing about the management of faecal waste from on-site sanitation systems, especially VIPs? What technologies are available, in South Africa and elsewhere for the emptying of VIPs? What new technologies for VIP emptying are under development and testing? What disposal options are available for faecal waste? What is the cost of faecal waste management? Is there any evidence for the effectiveness of pit additives? These questions are all significant in understanding the sustainability of dry sanitation systems.

Introduction

VIPs are indicated as the minimum acceptable level of basic sanitation by the Department of Water Affairs (DWA), which regulates the water and sanitation sectors. The Free Basic Sanitation policy devolves the responsibility for providing and maintaining basic sanitation to the local government level. Water Services Authorities (WSAs) are the bodies which carry out this task. Larger municipalities constitute their own WSA, while smaller municipalities may be grouped within an area and fall under a district WSA. In total there are 154 WSAs in the country.

After 1994 most expenditure in the water and sanitation sector focused on water supply, and the provision of sanitation lagged until 2000. VIP construction has proceeded apace since then, with the focus on toilet building but less attention afforded to the operation and maintenance of these systems. Pits have a finite capacity, and once they are full they no longer provide a sanitation solution for users. Most international experience with the provision of onsite dry systems has been community or household based, which establishes the elements of ownership and responsibility. The large scale roll-out of free basic sanitation in South Africa brings many challenges associated with the filling up of pits. The problems include poor construction of pits and linings, undersized pits, dumping of solid wastes and the addition of smell retardants and disinfectants. Bhagwan *et al* (16) highlighted that pits are in many cases filling up faster than expected.

Municipalities are accordingly facing challenges with planning and budgeting for the emptying of VIPs. They need to know what is happening at the household level in order to predict the rate of sludge accumulation and the emptying methods that may be required. Furthermore, they will have to dispose of the pit contents without endangering the health of residents or the functioning of existing wastewater treatment works, and do so with as little damage to the environment as possible.

In response to these emerging challenges, the Water Research Commission has commissioned a number of research studies to deal with providing solutions to this growing problem. The research covers aspects related to scientific understanding of processes in pits and the accumulation of faecal sludge, appropriate and innovative techniques for pit emptying, as well as the safe and beneficial disposal and management of faecal sludge. Preliminary findings are discussed below.

Survey of Water Services Authorities in South Africa

A survey, conducted by Partners in Development in 2008/2009, investigated the management of Ventilated Improved Pit Latrines (VIPs) by the Water Services Authorities in South Africa.

There are 154 WSAs in the country, and 109 of these indicated that there are VIPs within their jurisdiction. The total number of VIPs covered by the survey was between 1.2 and 1.5 million. The WSAs estimated that 85% of these are older than 5 years (see Fig. 1).

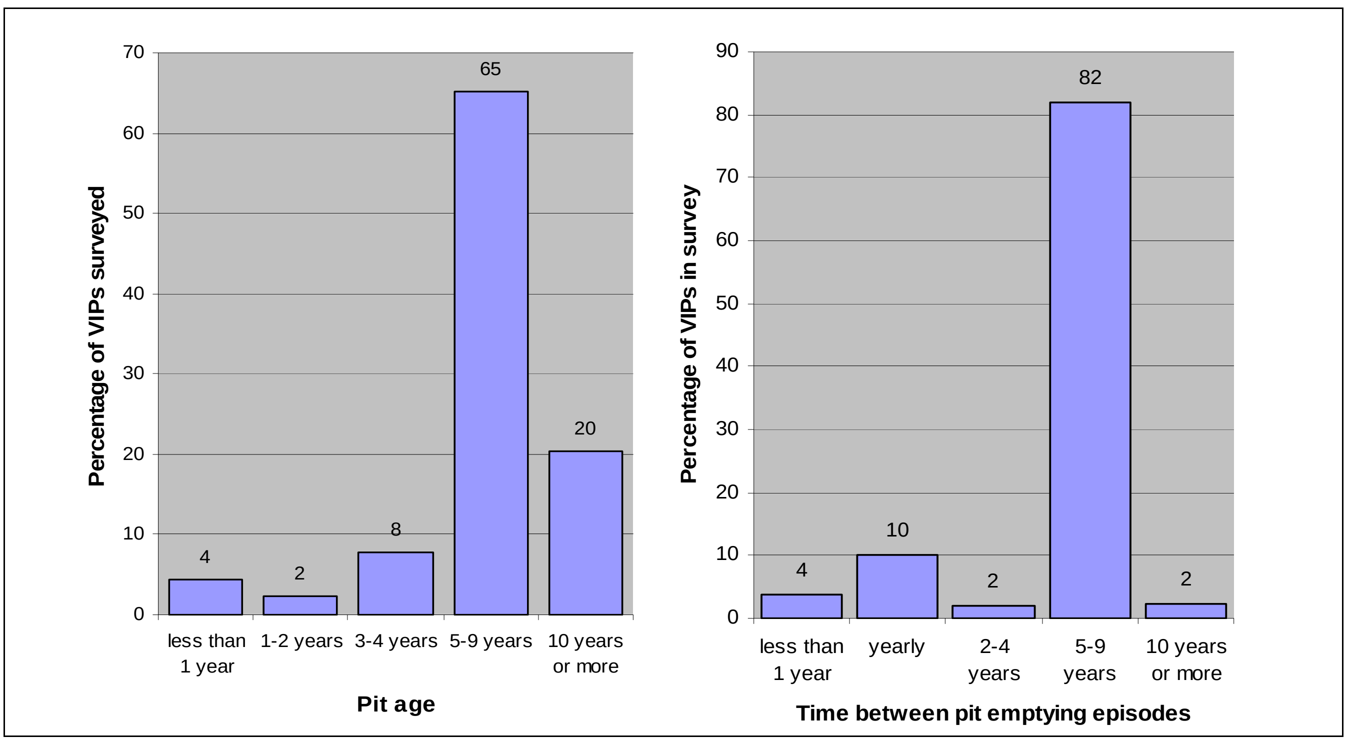

Figure 1: Age of VIPs and pit emptying frequency in WSAs surveyed by PID, 2008/2009

Figure 1 also shows the frequency of pit emptying as indicated by the WSAs. Most pits need to be emptied every 5 to 9 years. This figure suggests that pits are filling up more rapidly than was anticipated from previous studies and that a crisis of full pits is looming.

The cost to empty a pit could only be inferred from the data obtained from 21 of the respondents, and this value ranged from under ZAR 50 to over ZAR 5 000.

Ethekwini Water and Sanitation (EWS) is undertaking a large scale pit emptying programme. There are approximately 45 000 VIPs in the Ethekwini area, and the municipality plans to empty them once every five years. EWS employs a consulting firm to manage the project and a main contractor who manages eight sub contractors, each employing teams of emptiers. The average cost per pit emptied to 31 January 2009 was approximately R2 100, or R420 per pit per annum.

Sludge accumulation rates

A study commissioned by the Water Research Commission in Soshanguve in Gauteng (1) observed the accumulation of sludge in pit latrines over a two year period to be 24 litres per capita annum (l/ca). At this rate a family of 6 would accumulate 144 litres per annum, and hence a 2.5m^3 pit would last approximately 17 years.

Wagner and Lanoix (2) used data gathered by the World Health Organisation in the 1950s. They found that sludge accumulation was approximately 40 l/ca in wet pits where solid anal cleansing material was used. They recommended that 60 l/ca person per year be allowed for dry pits, and up to 50% more if large amounts of solid material (grass, stones etc.) were used for anal cleansing. These figures are still used as guidelines to calculate the life of pits (3, 4, 5), yet the original authors emphasised that pit filling rates should be developed for each country.

Two studies were conducted in 2009 to assess pit filling rates: one in a peri-urban area in KwaZulu-Natal (KZN) and the other in a group of rural villages in Limpopo province. The latrines in the KZN study were built in September 2006, while those in the Limpopo study ranged from 10 to 12 years old. The median observed filling rates are given in Table 1.

Table 1: Median pit filling rates

Area	Litres per pit per annum	Litres per user per annum
KwaZulu-Natal	307	42
Limpopo	296	39

The KZN latrines were subjectively assessed for the quantity of rubbish in the pits, and half were found to have a low or medium amount while half were deemed to have a high rubbish content. The mean filling rates for these two groups are shown in Table 2.

Table 2: Median pit filling rates for different rubbish contents

Rubbish level	Litres per pit per annum	Litres per user per annum
Medium/low	248	33
High	476	50

The frequency distribution of pit filling rates (Figure 2) shows two peaks which may be a result of these groupings.

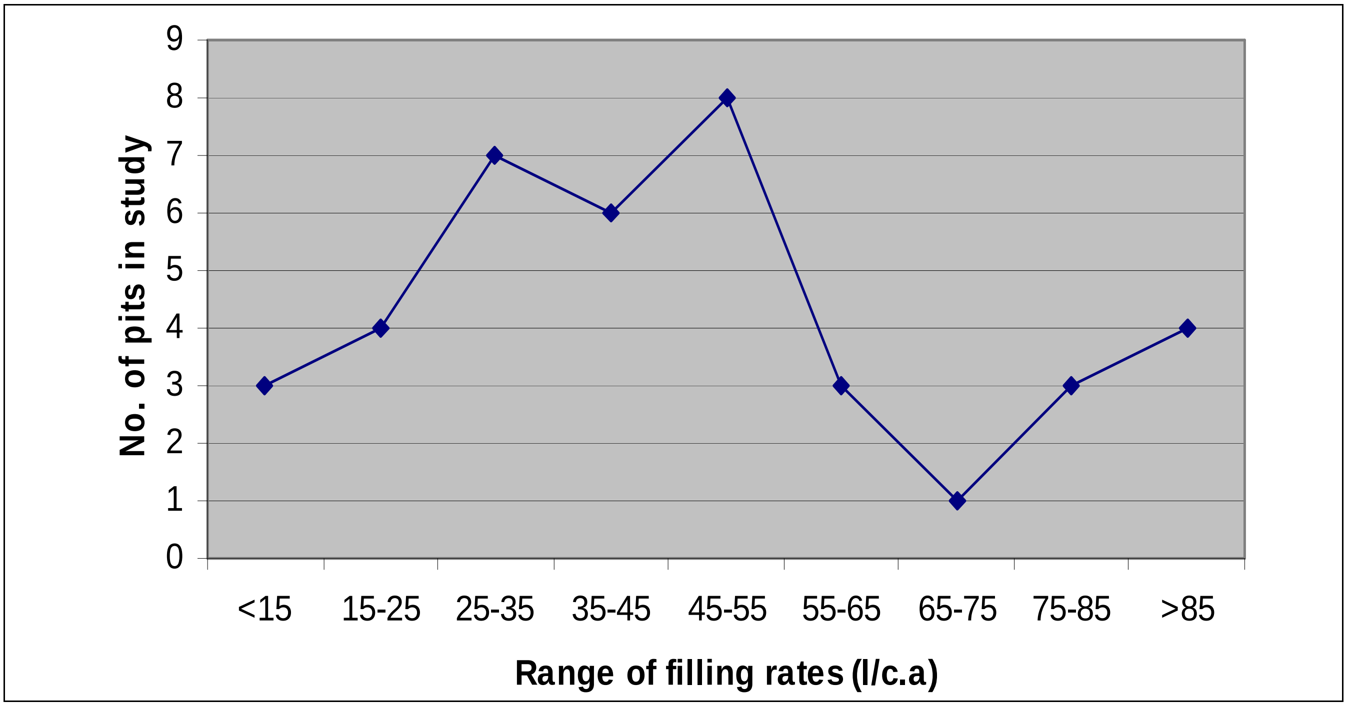

Figure 2: Frequency distribution of filling rates in the KwaZulu-Natal study

A further finding from both studies was that filling rates do not increase in direct proportion to the number of users. When user numbers were reported to be lower, the sludge accumulation rate per person was higher (see Fig.3). A possible explanation for this apparent anomaly is that numbers may include or exclude users who visit on weekends and the hope of obtaining a second latrine may inspire some to exaggerate user numbers. Other confounding factors may be the socio-economic status of different sized households and the number of children in larger families. This last issue is being investigated in a study which is taking place in eThekwini Municipality. This will provide more data on sludge accumulation rates.

Using data derived from the above studies, if the dates of construction of pit latrines are recorded, and the pit volumes are known, it is possible to predict the interval before desludging will be required.

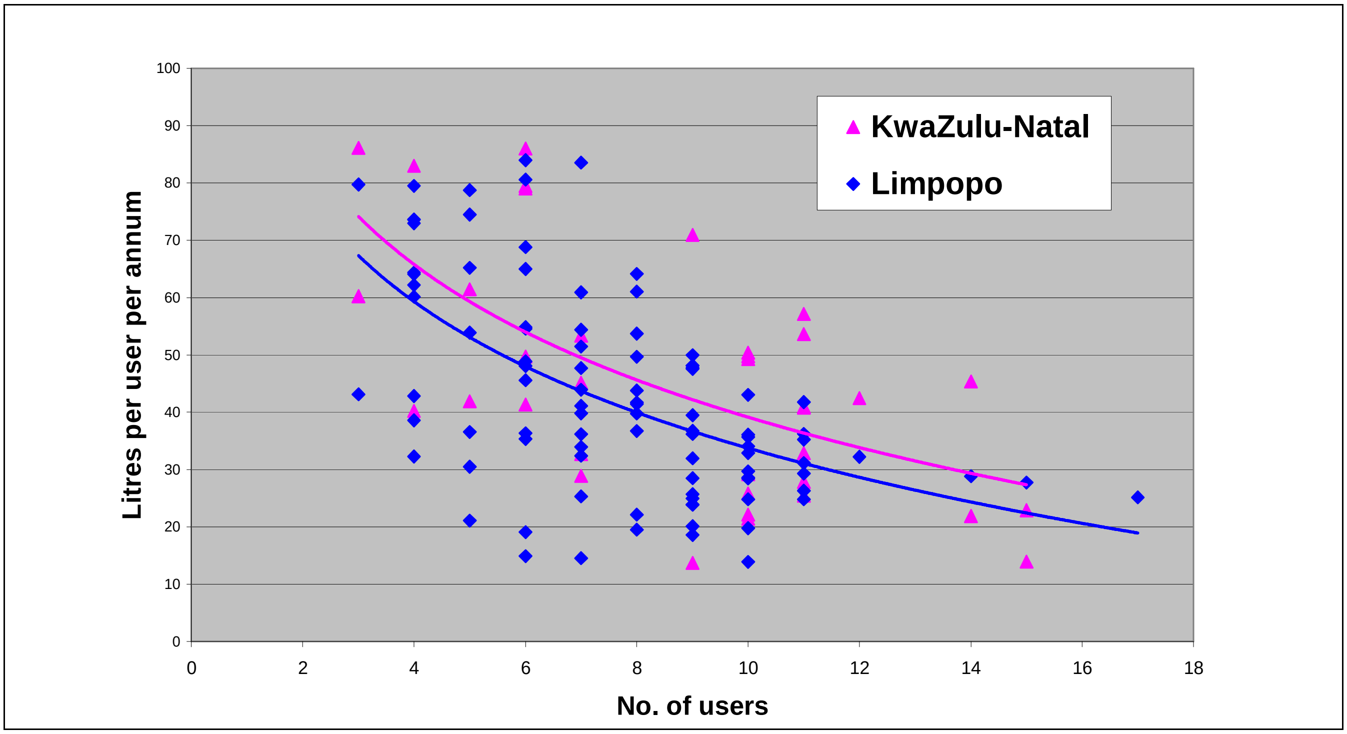

Figure 3: Scatter plot of observed sludge accumulation vs reported number of users

Pit additives

Additives which claim to reduce the volume of the contents of pits and hence increase pit life are very attractive to those faced with the problem of full pits. A review of research into pit additives for pig slurry found no evidence of solids reduction (6). The trials reviewed covered a range of additive types including those containing microbes and/or digestive enzymes. Foxon *et al* (7) did not find any improvement in mass loss or sludge stabilisation when commercially available additives were used with VIP sludge in laboratory scale tests. Enzymes have, however been shown to reduce solids in sewage sludge (8) and a pit additive containing marine algal extracts and plant-derived surfactants was reported to reduce total solids in an anaerobic pig slurry lagoon (9). Further investigation of the potential of additives seems warranted.

The survey of WSAs found that 20% of them are providing households with additives for VIPs, while 12% reported that they had decided against this. Budgets for additives range from ZAR13 to 250 per annum. Many products are available and municipalities report numerous visits from salesmen, with uncertainty still surrounding the merits of these products.

Trials of a product which has been successful in the market are currently being conducted (September 2009 – January 2010). These are taking place near Pietermaritzburg in KwaZulu-Natal, on the same pits for which sludge accumulation rates have already been calculated.

Forty VIPS were selected from an initial group of fifty, with all those where other products were being used excluded from the study. The latrines were divided into two blocks, based on the subjective assessment of rubbish content in the pits. Four treatments were randomly allocated within the blocks. The commercial additive, liquid molasses diluted with water in the ratio 1:5 and water coloured with food dye made up the first three treatments, while the fourth was a control with nothing added to the pits. One litre of treatment was applied to the pits every two weeks, in accordance with the manufacturer's instructions.

No change in sludge accumulation rates had been observed after 10 weeks. The users of all pits except the control (nothing added) reported a reduction in smell. The manufacturer of the additive suggested increasing the dosage to two litres for the remainder of the trial, which will run for 16 weeks. After 14 weeks, with the double dose having been applied for six weeks, there was still no discernible change in the sludge accumulation rate between the four treatments.

Pit emptying technologies

Most municipalities are equipped to empty septic tanks using a vacuum tanker. In some instances pit latrines may be emptied in the same way, but more often the nature of the pit contents and lack of access to the pits make this impossible. In South Africa at present, the main alternative to vacuum tankers is manual emptying using hand tools. This practice does carry a health risk, particularly when emptiers climb into pits to expedite the process.

Technologies more appropriate to these situations include the Vacutug, developed by UN-Habitat (10), the MAPET from the Netherlands organisation WASTE (11) and the Gulper and Nibbler, designed by Steven Sugden of the London School of Hygiene and Tropical Medicine (12). The potential for the use of this equipment in South Africa needs further investigation. There are still limitations, either in ability of these technologies to access pits in very steep or congested areas or to pump pit contents which are very dry or which have large amounts of foreign material. New or adapted technologies may be able to reduce the risk attendant on manual pit emptying.

The Vacutug is a pit emptying machine which is propelled by a petrol motor. The motor can be changed over to drive a vacuum pump in order to fill a vacuum tank which holds 500 litres. One has been used to empty the pits of low flush latrines in the Slangspruit area of Pietermaritzburg. Sludge was evacuated and transferred to a 5 m^3 holding tank which was emptied by a municipal vacuum tanker.

Figure 4: Vacutug, transfer tank and municipal vacuum tanker in Slangspruit, Pietermaritzburg

This operation employed two people, and proved cost effective at ZAR250/m^3 sludge removed (half of which was an allowance for machine costs, the other half labour), excluding the cost to empty the transfer tank. The sludge removed had little rubbish since the latrines are located inside the houses and waste must pass through a pipe to the pit.

A smaller vacuum pump, which can be coupled to a separate tank, has been developed and is being tested (see Fig.5). The “Nanovac” can be carried to places which the Vacutug cannot access. Tanks being used include a modified “Hippo roller”, which incorporates a handle and can be rolled from the vicinity of the pit being emptied to a transfer tank or a transporting vehicle.

A motorised auger which extracts material from pits is also in the testing phase (Fig.6). Chain based technologies, based on Steven Sugden’s “Nibbler” design have also been built and tested, but the tendency of the chains to block with solid material has proved challenging.

Figure 5: The Nanovac

Figure 6: Motorised auger

A modified version of the Gulper (12) has been tested by EWS and is proving successful for evacuation of wetter sludge. This hand powered pump fills containers with sludge, and these can then be removed from site.

Sludge disposal in plantations

Dumping pit latrine contents into the sewage system or directly into the wastewater treatment works will cause shock loading (16), and this is not recommended for large scale emptying programmes. Composting, landfill or incineration are possible options for pit sludge disposal. Composting may require the addition of further material with a high carbon content, such as municipal organic solid waste, which may be an expensive process (13). Burying sludge in landfill or incineration are both processes which fail to exploit the potential of sludge as a resource, as suggested by the Department of Water Affairs in the latest sludge guidelines (14).

Deep row entrenchment of wastewater treatment works sludge was pioneered in Maryland in the USA in the 1980s (15). This technique involves the use of earthmoving equipment to bury sludge in plantations before planting takes place. The anaerobic conditions in the trench have been found to inhibit nitrification thereby limiting the leaching of nitrates. The entrenched sludge has then been found to provide a form of slow release fertiliser for trees.

In areas where there is enough land for on site disposal of sludge emptied from VIP latrines, this is by far the simplest and most economical disposal method. A disposal pit is dug on the same plot at a site designated by the home owner, preferably fairly close to the pit latrine, and the pit sludge is afterwards covered with heaped soil. The pit contents are high in organic nutrients and homeowners should be encouraged to plant a tree on top of the disposal pit. However, in dense peri-urban areas this disposal method may not be possible.

The alternative options for the disposal of pit latrine sludge are limited by some of its characteristics. It has a lower moisture content than sewage or septage, and therefore cannot be treated in stabilisation ponds or anaerobic reactors without the addition of water. It may contain large amounts of non-biodegradable matter, such as plastic, metal and wood, so requires extra screening before it can be disposed of in a sewer. It has a high pathogen content and a strong odour, and human contact with it should be strictly limited. It is moreover so concentrated that only relatively small volumes of VIP sludge can be added to the inflow to a waste water treatment plant before the plant's ability to function properly becomes seriously compromised.

Deep row entrenchment was selected as a suitable option to overcome these difficulties. It reduces risk of pathogens coming into contact with people, allows the disposal of non faecal matter and recycles nutrients in accordance with the latest sludge guidelines.

The eThekwini Municipality offered the use of land at the site of former sewage treatment ponds in Umlazi, south of Durban. VIP sludge has been buried and *Eucalyptus grandis*, Eucalyptus *grandis X urophylla, Acacia mearnsii* and banana seedlings have been planted. Fig. 7 shows these trees at planting in early 2009, and nine months later.

Five ground water monitoring boreholes were sunk on the downslope side of the site, and monitoring of levels of *Escherichia coli*, nitrate, ammonium, chloride, sodium is being carried out. Electrical conductivity, heterotrophic plate counts and COD measurements are also taken monthly.

The assessment and monitoring of the water and mass balance on the site is ongoing. Characterisation of the hydraulic properties of the soils and subsurface were carried out, with the initial surface hydraulic conductivity measured and Electrical Resistivity Tomography transects completed. Site instrumentation is in place to monitor water and solute movement and initial analysis of the site water balance and mass plume has been performed to establish profiles for HYDRUS2D runs.

A sludge entrenchment trial has also been initiated at a SAPPI plantation site near Howick. Wastewater treatment works sludge has been used for this experiment, applied at three different nitrogen application levels: approximately 2 250 $kg.ha^{-1}$, 4 500 $kg.ha^{-1}$ and 6 750 $kg.ha^{-1}$. Two controls will be used: one in which trenches have been dug but no sludge will be applied, and one in which the soil will be undisturbed. These treatments have been randomised over 30 plots and planting will be taking place in January 2010 according to the normal commercial planting procedure. Tree growth and wood quality will be monitored, and similar water and mass balance instrumentation and ground water monitoring bores will be established on site.

Figure 7: Eucalyptus trees at planting and after 9 months, deep row entrenchment site, Umlazi, Durban

Discussion

WSAs will need to develop rapidly the capacity for emptying large numbers of pits. The survey did not indicate that this problem is being addressed in a coordinated fashion, nor that effective planning and budgeting is happening. A costing which includes the necessary managerial costs, health and safety costs and realistic labour and equipment costs would allow municipalities to budget and to monitor pit emptying programmes more effectively. This costing is part of the WRC projects in process.

The sludge accumulation studies indicated that a simple linear relationship between user numbers and pit filling rate may not exist. Numbers may include or exclude users who visit on weekends. Other confounding factors may be the socio-economic status of different sized households and the number of children in larger families. The two studies reported here have similar median values (39 and 42 litres per capita per annum) but the scatter plot shows that a more conservative value, up to 60 litres per capita per annum, should be used in planning a pit emptying programme if most VIPs are to be emptied before they become unusable. The difference between the median filling rates between higher and lower pit rubbish levels highlights the importance of solid waste removal and user education if the life of pits is to be prolonged.

While there is in some quarters a belief in the usage of enzymes and other biological agents (additives) to reduce the rate of sludge accumulation in pit latrines, work carried out in this and other studies both in the field and in the laboratory has failed to find any evidence to support this belief. In the absence of any scientific evidence for the efficacy of these products, they appear to represent a poor investment.

An important area of research and development is the need to develop small-scale pit emptying technologies that can be carried to sites inaccessible by road, and that will make it possible for pits to be emptied cost-effectively, quickly and with a minimum of discomfort or risk to the pit emptying team and the owners of the pit. Various development efforts in this regard are underway in South Africa and elsewhere.

Once pits are emptied the final question is how to dispose of the sludge. The simplest and most cost-effective is some form of land fill, preferably close to the removal site. In rural areas with large plots on-site disposal is often possible. In denser peri-urban settlements the use of pit sludge buried in deep rows in conjunction with tree plantations may provide a safe disposal option and simultaneously enable the organic nutrients bound up in the sludge to be beneficially used. In 2009 sludge disposal agroforestry sites have been established to test this concept, one hectare in Umlazi, near Durban and 2.5 hectares near Howick. Tree growth, tree health and groundwater contamination will all be closely monitored.

Acknowledgements

This work is being funded by the Water Research Commission. The eThekwini Metropolitan Municipality has provided essential co-operation and support.

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