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Challenges with up-scaling dry sanitation technologies

J. N. Bhagwan, D. Still, C. Buckley and K. Foxon

ABSTRACT

The acceleration of sanitation delivery towards meeting the South African Government's target of completely eradicating the existing backlogs by 2010, has led to a surge of activities. As part of its strategy for ensuring that basic sanitation is provided, the policy has recommended that a ventilated improved pit latrine (VIP) is considered as the basic minimum requirement in the form of a sanitation technology. The up-scaling and delivering of sanitation in many cases in the form of VIPs and its derivatives, as well as urine diversion technology are beginning to pose many technical challenges. The principles on which they have been designed are not always being observed in practice. As a result, some systems are filling up much faster than expected. Research has found that the breakdown in the faeces is not happening as would be expected in an anaerobic reactor, and that the drying of faeces in humid conditions, even with the use of drying agents, is not optimum. These problems, which are being experienced in the field, will have long term repercussions on the sustainability of sanitation provision. This paper aims to share these experiences and findings of research, and the impact it may have on the Sanitation MDG goals.

Key words | on-site dry sanitation, pitlatrines, sludges, urine diversion, ventilated improved pitlatrines

J. N. Bhagwan
Water Research Commission,
Private Bag X03, Gezina—0031,
Pretoria,
South Africa
E-mail: *jayb@wrc.org.za*

D. Still
Partners in Development (South Africa),
PO Box 11431, Dorpspruit 3206,
South Africa
E-mail: *dave @pid.oc.za*

C. Buckley
K. Foxon
Pollution Research Group—University of Kwazulu- Natal,
Durban 4041,
South Africa
E-mail: *buckley@ukzn.ac.za*; *foxonk@ukzn.ac.za*

INTRODUCTION

The Millennium Development Goals (MDGs) are a set of targets to extend the benefits of development to a substantially increased proportion of the world's poor. At the World Summit on Sustainable Development in 2002, the extension of sanitation to the poor was added to the MDG targets. Accordingly, the MDG target was to halve the proportion of people in the world not having access to basic sanitation by 2015. This commitment was important as it ensured that national governments and international agencies raised the priority of and the funding for sanitation. Recent estimates note that 2.6 billion of the world's population lack access to basic sanitation. At the current rate of water and sanitation development the world will miss the MDG target (to halve, by 2015, the proportion of people without access to basic sanitation) by 1 billion (Evans 2005; United Nations 2007). The impetus created by the MDG target has set in motion an upsurge in sanitation provision around the world. In South Africa, there is a strong political will and the necessary fiscal backing to eradicate the sanitation backlog which was inherited after the years of apartheid. In 2005 the Minister for Water Affairs, Buyelwa Sonjica, said that around 16 million South Africans remain without access to hygienic sanitation facilities, 3.6 million citizens with no access to safe drinking water, and a further 5.4 million who had a source of safe water, but more than 200 metres from their homes.

CHALLENGES POSED IN THE UP-SCALING OF ONSITE DRY SANITATION SYSTEMS

Many VIP latrines have been built with permanent superstructures. In designing a VIP the main component is the sizing of the pit, which is based on the volume

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of faecal waste that accumulates per person per year ($r = 0.05\,m^3$/person/year), the number of users (P) and the design life of the pit (n = usually 10 years). Pit working volume = rPn (m^3). The same formula is used for sizing alternating twin pit systems. Field experience in South Africa has raised the following concerns.

- Pits are filling up much faster than their design life.
- There is conflicting advice on what should be put into pits to keep them operating well.
- A variety of undesirable non-degradable objects are introduced into pits which may complicate pit emptying exercises.
- A range of disinfectants are used which may negatively affect stabilisation processes in the pit.
- Emptying of pit contents poses significant health risks and organisational difficulties.
- Poor construction results in problems with structural integrity, flies and odours.
- Grey water is frequently added to the pit as there is no other mode of disposal, under certain circumstances this can lead to groundwater pollution.
- There is a tendency to use pits for the disposal of household waste, much of which is non-biodegradeable.
- Despite education programmes which strongly advise against this, many users are in the habit of dosing their pits with disinfectants to reduce odours and poison such as sheep dip to reduce fly breeding.
- There is a lack of the necessary anaerobic activity in the pit or break down in the material.

The implications of these developments are profound and will have a huge impact on the sustainability of the technology and sanitation in general.

- Shorter lifespans mean an increase in maintenance costs should the desludging of pits be required. This is expensive and becomes very difficult if the pits and superstructures are not designed to allow for desludging.
- Should desludging prove difficult, then the other option is to build new VIPs, which is expensive and contributes to the sanitation backlog.

Thus it is a matter of urgency that a thorough understanding of the technology is determined so that the technology can be influenced to be more effective. To date, little research has been carried out on understanding the degradation mechanism or processes occurring in VIP latrines. We have come thus far with the understanding and assumption that the mechanism in pits is predominantly an anaerobic degradation process. Specifically, there is limited understanding of the:

- physico-chemical characteristics of pit contents at different points in the pit;
- biodegradability of pit contents at different points in the pit;
- methanogenic activity at different points in the pit.

The majority of the material in a VIP pit is not exposed to oxygen (either directly to oxygen gas or through diffusion through water). Thus, if any biological degradation is to take place in the bulk of the pit, it must do so anaerobically. Unlike engineered wastewater treatment systems, there is no mechanism in a VIP pit to select and retain or recycle specific types of micro-organisms, further there is no generally applied inoculation or seeding mechanism to ensure that suitable micro-organisms are present. Furthermore, the comparison of the contents of different VIPs is found to be very non-homogeneous. The South African Water Research Commission has initiated a number of research studies to develop a scientific base to understand the VIP technology and find ways to mitigate the current experiences and develop solutions, as discussed below.

Pit filling rates and outcomes of research

A key factor in determining the operations cost of pit latrines is the rate at which the latrines can be expected to fill up. The rate of sludge accumulation in septic tanks and digestors is a topic better researched than the rate of filling of pit latrines. The WRC Report (WRC 2000) recommends that the filling rate of 29 litres/capita/annum are used as a design criteria for septic tanks, but quotes data from local and international experience which shows that filling rates vary from less than 10 litres per person per year to over 100 litres per person per year. Data quoted by Still (2002) shows an equally wide range of sludge accumulation rates in pit latrines.

Table 1 shows results from six studies. In this table the one case where the filling rates were found to be

Table 1 | Observations of pit filling rates (after Still 2002)

Location	Reference	Age of latrines	Number of sites monitored	Number of visits	Avg. pit volume m^3	Range of filling rates observed litres/capita/annum	Mean filling rate l/c/a
Soshanguve	WRC Report	Approx. 3 years	11	14 over 28 months	1.96	13.1 to 34.0	24.1
Bester's Camp	City of Durban Report	4 years	159	2 or 3 over 25 months	3.16	18.3 to 120.5	69.4
Mbila	Partners in Development Report	Approx. 5 years	11	1	2.83	10.0 to 33.2	18.5
Gabarone, Dar es Salaam	WHO paper, 1982	Not stated	Not stated	Not stated	Not stated	25 to 30	27.5 (implied)
Mbazwana	Partners in development report	11 years	19	1	3.40	14 to 123	29 (median)
Inadi	Partners in development report	11 years	25	1	2.00?	14 to $>$ 77	34 (median)

significantly higher was Bester's Camp, near Durban (Gounden *et al.* 2006), where the mean filling rate was found to be 69 litres/capita/annum. Indications are that this rapid filling is due to latrines in this area being poorly drained. Health precautions for emptying pits and the disposal of the sludge are stated in the draft DWAF guidelines (DWAF 2005). Table 2 lists various methods of pit emptying and their relative costs.

In 2004 the eThekwini Municipality made a thorough study of the cost of pit emptying (Macleod 2005). The cost of emptying VIP pits varies according to method used, pit contents and accessibility. A large number of the pits are in locations that are inaccessible to standard emptying machinery, and manual methods had to be used (see Figure 1). In fact, the most cost effective option was found to be the use of labour where the waste material in the pits was removed manually using buckets and spades. The waste is then loaded into 100 litre steel drums which are manually moved on trolleys to the nearest road for removal from site. Although the costs of pit emptying

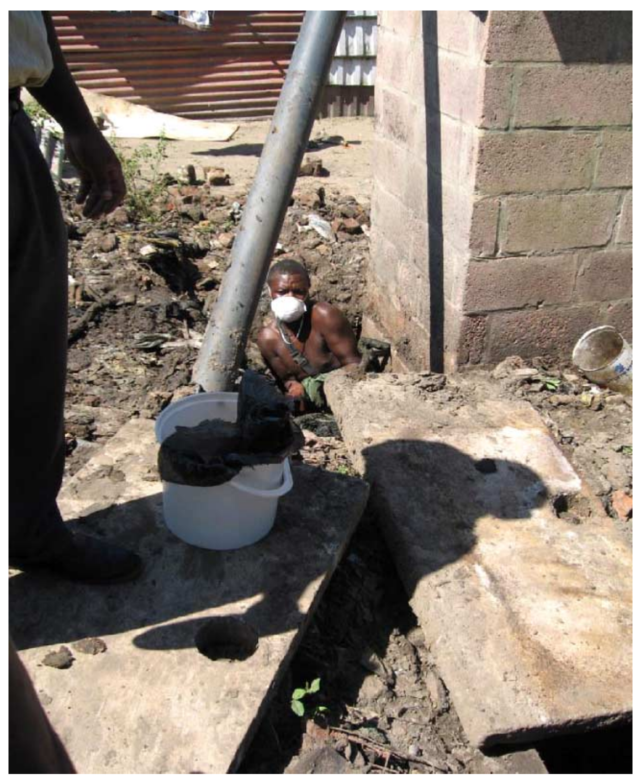

Figure 1 | Pit emptying.

Table 2 | Types of pit emptying and associated costs (after Still 2002)

Methodology	Source of information	Cost (range) for 2 m^3
Manual excavation Old pit with fully decomposed contents	Standard rates for Pit Excavation in Soil	R70 to R140
Manual scooping/flushing (Dar es Salaam) Handtools only	MAPET Report, SA contractors	R50 to R110 (for 2 m^3, but reported pit size is 10 m^3)
MAPET (Dar es Salaam) Cart mounted 200 litre vacuum tank indirectly coupled to handpump	Jaap Rijnsburger, WASTE	R80 (but not covering capital or support costs)
VACUTUG (Nairobi) Self propelled 500 litre tank with motorised pump	Graham Alabaster UNCHS, Nairobi	R180
MINIVAC (Durban) Trailer Mounted, Tractor hauled 2000 litre tank	SA Contractors Lesotho	R200 to R600 low rate only applies for large scale scheduled work
VACUUM TANKER–URBAN 5,000 to 15,000 litres truck mounted tank	SA Contractors	R200 to R1000 depending on efficiencies R600 default
VACUUM TANKER–RURAL 5,000 to 20,000 litres truck mounted tank	SA Contractors	R7 to R15 per kilometre return e.g. 200 km return $>$ R1,400

Note: To adjust the above costs to 2007 Rands they should be factored by 1.35. To convert to equivalent USD they should be divided by 7.

operations during the pilot programme ranged from R1185 to R1702, it was estimated that by using the most cost-effective method (i.e. manual) and by programming pit-emptying in an efficient manner, these costs could be reduced to an average of R629.80 (UWP 2004). However, in 2007 when the eThekwini Municipality commenced a five year programme to empty 50,000 VIPs, the actual costs were expected to be in the R1000 to R1100 range (WIN-SA 2006). This cost does not, however, take into account the impact of pit latrine sludge at the waste water treatment works where it is disposed. An analysis of the relative concentration of total suspended solids and nitrogen (measured as TKN) in pit sludge shows that the impact of just one pit latrine's sludge on a waste water works is equivalent to the loading of between 500 m^3 and 1,000 m^3 of typical sewage. This means that even a relatively large works cannot deal with more than a few loads of pit sludge in a day, and there is a significant cost in the processing of this sludge.

Apart from cost there are practical difficulties in emptying pit latrines. Experience in the eThekwini area shows that pit emptiers find it necessary to climb inside the latrine vault in order to fully empty the latrine, which exposes them to a significant health risk.

In Durban, South Africa, manual methods have been found to be the most practical and economical for pit emptying. However, for this to be an acceptable long term solution, thought must be given to pit design and worker health and safety.

WHAT HAPPENS IN THE PIT?

A Water Research Commission project investigated the biological and chemical processes that occur in a pit latrine (WRC 2007). What is added to a pit depends mostly on user habits and to a lesser extent on the physical design of the structure. What occurs in the pit depends to a certain extent on the same two factors; in addition, the geo-hydrology of the locality of the pit will also affect the processes that occur therein.

- *Accumulation*: Material that does not degrade or drain out of the pit will accumulate and cause the volume of pit contents to increase.
- *Aerobic degradation*: In the presence of oxygen and appropriate aerobic micro-organisms, biodegradable material will be converted to CO_2, water and more cell mass for the participating micro-organisms. This can only occur on the very top of the pit contents since oxygen is very quickly depleted below the first few millimetres of pit contents. Research has indicated that aerobic stabilization of the most easily biodegradable

components of faecal matter occurs on the surface of the pit, shortly after being added.

- *Anaerobic degradation*: In the absence of oxygen, and in the presence of appropriate anaerobic micro-organisms, provided that environmental conditions of pH, moisture and other chemical factors are correct, anaerobic digestion of biodegradable organic compounds will occur resulting in the production of intermediate products including soluble organic compounds, especially organic acids and end products including CO_2, CH_4, water, non-biodegradable organic material, NH_4^+, phosphates and a small amount of new anaerobic micro-organisms. This study has shown that a considerable amount of anaerobic stabilization may occur in pit latrine contents, but that the rate and extent of degradation is largely limited by chemical factors such as pH, amount of moisture available and presence of inhibitory substances
- *Physical mass transfer*: the physical nature of the solids affects the mass transfer of substrates to the micro-organisms and the waste products from the micro-organism. Too dry a system will encounter problems due to viscosity and osmotic pressure limitations. Excess water in a draining environment would allow soluble substrates to leach from the pit, possibly slowing the biological processes.
- *Leaching/draining*: depending on the type of soil/rock in which the pit is located and the height of the water table, liquid and soluble components may move in or out of the pit. Under many conditions, liquid carrying soluble and suspended material will percolate through the pit contents or out of the pit walls and drain away, resulting in fairly dry pit contents. However, when the water table is high, or there is some other source of moisture above the bottom of the pit (e.g. a tap located near the pit or movement of water after heavy rains) moisture may move into the pit, bringing in soluble and suspended material from the surroundings.
- *Digestion by macro-invertebrates*: Fly larvae and other worm-like macro-invertebrates are observed in the contents of many pit latrines. These have two important effects: (i) they digest pit latrine material, thereby providing a degree of stabilisation and volume reduction; and (ii) movement of macro-invertebrates in the top layers of the pit latrine contents ensures aeration of a thicker layer than would occur in their absence. However, fly larvae generally indicate poor construction and may constitute a health hazard.

Given the variability in the nature of material that enters a pit latrine, it is impossible to say how much stabilisation has already occurred in a sample. However, during the course of this study, some pit latrine contents were observed to be essentially un-degraded, while material from other pits appeared to be almost completely stabilised. The implication is that a wide range of stabilisation rates appears to be possible in pit latrines. Further research is needed to understand the reasons for these variations. Stabilisation rates were found to be adversely affected by the use of disinfectants but could be enhanced by increasing moisture content and alkalinity content provided that the pH conditions remain in an appropriate range for microbial activity (pH 6.5 to pH 8) and that other limiting conditions were not present.

A literature review indicated that pathogenic micro-organisms should be completely eliminated within pit latrine contents after a retention period of 1 year, with the possible exception of helminth eggs. The age of the contents of pits range from minutes to 10–15 years. Although a systematic observation of pathogen loads was not made in this study, examination of face masks used by workers involved in emptying full pit latrines showed that the load of helminth eggs of the genera *Trichuris*, *Taenia* and *Ascaris*, to which pit emptying workers were exposed, was very high. The implication is that even if pathogens have been activated in the bulk of sludge, any activity that involves the handling of pit latrine sludge is inherently risky.

IMPLICATIONS OF RESEARCH FINDINGS ON LONG TERM SUSTAINABILITY OF VIPS

VIP planning and design dates from a time when government interventions was minimal and toilet construction mostly owner driven. Therefore, not much thought was given to what would be done when the pits filled up. The toilet owners and users could build a new toilet as often as required. South Africa is now in a supply driven mode, with a target to have sanitation for all by the year 2010. Moreover, in 2001, the government adopted a policy that the basic level of municipal services, provisionally defined as access to 6 kL of water per family per month, at least a VIP toilet, a basic amount of energy provision and also the provision of a solid waste refuse removal service should be provided to the poor free of charge. Free basic sanitation, in terms of the Strategic Framework for Water Services, which was published in 2003, also includes the operation and maintenance of the sanitation service. This implies that the pit emptying service is a part of its commitment to free basic sanitation. Therefore, design must take this into account. Absolutely unacceptable is a heavy permanent structure single pit VIP with access to the pit only through the pedestal (Morgan 2005).

Access to VIPs for emptying has not been given enough attention. If manual emptying is the only method that is practically and economically possible, then pits should be provided with removable slabs, preferably at least two. Furthermore, the required pit volumes should be achieved by increasing pit area rather than pit depth, as it is very difficult to manually empty a pit which is deeper than 1.5 metres without the worker having to get into the pit, and this should be avoided.

The disposal of pit sludge to waste water treatment works has been found to be unacceptable and uneconomical, both from a transport and from a waste handling point of view. A simpler, more economical and probably more beneficial option appears to be the burial of the pit sludge as near as possible to the latrine. Studies in Zimbabwe (Robinson 2002*a,b*), United States, Australia and Indonesia indicate that buried faecal sludge is particularly useful as a slow release fertilizer for use in orchards and tree plantations, and more research into this disposal method is recommended.

CONCLUSIONS

The implications of these research findings and observations are profound and have a huge impact on the sustainability of the technology and sanitation in general.

- Once an on-site sanitation system is full, it can no longer fulfil its function of providing safe, hygienic and dignified sanitation for its owners. Thus, despite owning a pit latrine, the users do not have access to basic sanitation and therefore count as unserved.
- The costs of dealing with full pit latrines are high, comparable in many instances to the costs of installing new pit latrines. Theoretically, there are two options for dealing with full pits: (i) the pit contents may be removed manually or by pumping; or (ii) the pit contents may be covered over and a new pit dug nearby.
- When poor construction results in flies and odours, the pit latrine does not fulfil its function of providing safe and dignified sanitation to the users and may in fact constitute a health hazard.
- When bad user habits result in poor stabilisation rates in the pit contents, the rate of pit filling increases, as does the unpleasantness of the material that must be removed once the pit is full.
- There is no policy allowing the upgrading of on-site sanitation systems (*climbing the sanitation ladder*).
- When user convenience and comforts are impacted on due to the performance of the technology, it will surely affect sanitation behaviour and fail.

Onsite dry sanitation technologies are able to provide long-term, safe and dignified sanitation to users provided that a number of general rules are observed:

- The pit latrine sub-structure and superstructure must both be properly constructed to prevent collapse, to control flies and odours, and to facilitate emptying if this will be required.
- Pit latrines that will require emptying by persons other than the householder should only be constructed when it is conceivable that a pit emptying system will exist by the time the pit fills up.
- Where there is no plan to develop a pit emptying service, it is recommended that a system that can be managed by the householder, such as the eThekwini-style urine diverting double-pit composting latrine, would provide fewer challenges for operation and maintenance than a conventional pit latrine.
- The size of a pit is a compromise between the time it will take to fill the pit and the difficulty of emptying the pit. A pit that is 1.2 to 1.5 m deep may be emptied relatively easily, but may be expected to fill up far quicker than a pit which is 2–3 m deep. The size should therefore depend on a range of factors, including accessibility for pit emptying equipment and frequency at which the pit is likely to be emptied.

- Many of the difficulties associated with emptying pit latrines are related to solid non-degradable refuse in the pit. By ensuring that an effective solid waste removal system is in place in a community. and educating users to not put non-degradable refuse into their pits, the frequency and difficulty of emptying will be substantially reduced.

These experiences and the research findings are of international relevance. There is a risk that the large-scale roll-out of low-cost, on-site systems that are poorly designed and poorly understood will not assist in achieving MDG and national targets, but rather prove unsustainable, fail to improve quality of life and create new problems for policy makers and service providers when they fill up or fail. Long term operation and maintenance support must be considered when scaling up in the use of the technology. Also, by developing a comprehensive understanding of the social, technological, economic and health aspects of pit latrine design, operation and management, it may be possible to develop detailed guidelines that will promote the sustainability of basic on-site sanitation systems. Otherwise we will be chasing a perpetual sanitation backlog.

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