as near as possible to the latrine. Studies in Zimbabwe, United States, Australia and the 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.

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 being in possession of a pit latrine, the users do not have access to basic sanitation and therefore must be regarded 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 to guide the upgrading of on-site sanitation systems (climbing the sanitation ladder).
- When user convenience and comfort is impacted on by poor performing technologies, users' sanitation practices are likely to be impacted on negatively. Morever, the benefits of government's commitment to and investment in sanitation improvement are compromised.

## Recommendations

On-site 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 substructure and superstructure must be constructed properly to prevent collapse, control flies and odours, and 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 likely that a pit emptying service will be available by the time the pit is full.
- Where there is no plan to develop a pit emptying service, it is recommended that alternatives to a conventional VIP toilet are considered, which can be managed by the householder. The eThekwini-style urine diverting double-pit composting latrine, for example, provides fewer challenges for operation and maintenance than a conventional pit latrine
- The optimal 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 it may be expected to fill up far more quickly 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 about the consequences of putting non-degradable refuse into their pits, the frequency and difficulty of emptying will be substantially reduced.

## General conclusions

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. Instead, a significant number are likely to prove unsustainable, fail to improve quality of life and create new problems for users, service providers and policy makers when they fill up or fail.

Long term operation and maintenance support must be considered when scaling up in the use of the technology.

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. Without this, South Africa is likely to face a perpetual sanitation backlog.



WATER RESEARCH COMMISSION

October 2007

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

POLICY BRIEF

## SANITATION

**Management of full toilet pits poses complex challenges for households, local authorities and policy makers. VIP toilets which fill and become unusable within a few years compromise the objectives of the national sanitation programme. New research sheds light on the requirements for optimal, long-term functioning of pit toilets, and makes recommendations for design which facilitate sound maintenance**

# Design and operating requirements to optimize the life span of VIP toilets

(Outcome of WRC Project1630; Report No 1630/1/07)

## Ensuring VIPs function effectively

Ventilated improved pit latrines (VIPs) represent the minimum level of sanitation infrastructure that is deemed acceptable in South Africa.

Yet until recently, there has been limited investigation of the factors which determine the rate at which the toilet pits fill, or what impact local ground conditions have on the nature of biological activity within the pit.

The basic processes occurring in a VIP are:

- Filling with faecal material, water and other material
- Water transfer into and out of the pit
- Biological transformation, and
- Pathogen deactivation.

In principle, the rate at which the pit contents break down through biological activity should be similar to the rate of filling, thus providing a long service life for the pit. In practice, it is often observed that pits fill rapidly, particularly if a significant portion of the material added to the pit is non-degradable.

Management of full pits poses a number of complex challenges to policy-makers, local authorities and householders. Households with full unusable pits are no better off than those with no sanitation at all.

VIP toilets should therefore be designed and used in such a way that the pits take the longest possible time to fill, without causing environmental damage.

One approach being proposed to extend the life of a filling or full pit is the application of commercial pit latrine additives. These may be chemical, microbiological or enzymatic in nature . The additives are promoted as being able to reduce (or even reverse) the sludge accumulation rate in pit latrines, and also to reduce potential problems of flies and odours.

While anecdotal evidence suggests that they may well be effective, independent scientific evidence of their efficacy is scarce. Equally, a number of informal studies have suggested that these additives do not perform significantly better than the addition of plain water or inert additives (in effect, a placebo).

Clearly, where sanitation objectives are not being met because of sub-standard efficacy of VIPs in practice, corrective action is needed. To be successful, such action must be based on a scientific understanding of the source of the problem and the approach required to resolve it.

Field and laboratory investigations of VIPs and their contents have been undertaken in and around the eThekwini municipal area, in order to understand the conditions prevailing in the pits and to propose design and operating practices for extending the life of pits.

The study concentrated on three main areas of interest:

- The movement of liquid within and out of pits
- Nature and stabilisation rates of pit contents
- The action and efficacy of additives on biological processes taking place in the pit

## Movement of liquid

The moisture content of a pit has critical implications for biological activity within the sludge, and therefore the rate at which the pit fills. Greater activity takes place in areas with higher moisture content.

The investigation showed that the moisture content of pit material varies significantly from pit to pit and from area to area, and even within the same pit at different times of year, depending on local and seasonal conditions. There is no generic model of water movement that can be used to predict what the moisture content will be throughout the pit. However, in dry, porous soil conditions, liquid preferentially flows off the upper surface of the pit material and through the pit walls, rather than percolating down through the pit contents, where the resistance to moisture movement is high. The opposite may be true in pits located in hard rock or in clay soils. Where the water table is high, ingress of water through the pit walls is likely to occur.

The effect of liquid moving out through the pit walls at the upper surface of pit contents rather than down through the pit material, as well as the continuing slow moisture loss through pit walls deeper down, means that in dry surroundings the deeper pit material gets progressively drier with increasing depth in the pit.

The movement of liquid in and out of pits and the resulting moisture distribution affects the rate of biological activity, and therefore the stabilisation rates of pit materials in different areas of the pit. Greater activity takes place in areas with higher moisture content.

## Stabilisation rates in pit latrines

Examination of pit contents reveals that a great variety of materials are introduced into pit latrines. Besides excreta and cleaning material, many kinds of solid waste was found. Such a variety has a profound effect on both the rate of pit filling and on the stabilisation rate of the pit contents. The resulting wide range of stabilisation rates within a single pit results in some pit content being essentially undegraded, while other material is almost completely stabilised.

When most of the pit content originates from faeces, a large proportion of the organic material is degraded soon after entering the pit. In pits which are 'working well' (i.e. pits with healthy biological activity), digestion and stabilisation will continue as the depth increases, despite the fact that the moisture content is decreasing. However, stabilisation rates may still 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).

## Deactivation of pathogens

Pathogenic micro-organisms should be completely eliminated within pit latrine contents after a retention period of one year. Helminth eggs, however, are a notable exception.

Examination of face masks used by workers involved in emptying full pit latrines showed that the load of helminth eggs to which they were exposed was very high. This indicates that even if pathogens have been inactivated in the bulk of sludge, handling of pit latrine sludge requires great care as they still contain worm eggs that can hatch and continue the cycle of worm infestation.

## Challenges posed in the upscaling 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 of faecal waste that accumulates per person per year ($r=0.05$ m³/person/year), the number of users (P) and the design life of the pit (n=usually 10 years). Pit working volume = rPn (m³). Thus the standard pit volume for a family of six is three cubic meters.The same formula is used for sizing alternating twin pit systems.

A review of field experience in South Africa has identified the following challenges:

- Pits are filling up much faster than their intended 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
- 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 accelerate the rate at which the pit fills; in other circumstances it 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 add poisons such as sheep dip to reduce fly breeding. This compromises biological activity and stabilisation.
- There is very little anaerobic activity in the pit to break down in the material.

The implications of these findings are profound and have a huge implications for the sustainability of the technology and sanitation improvement in general.

- Shorter pit lifespans mean an increase in maintenance costs, should pit desludging of pits be required. Pit desludging is expensive and becomes very difficult if the pits, superstructures and surrounding areas are not designed to accommodate desludging.
- Should desludging prove difficult, the alternative is to build a replacement VIP toilet. This is expensive and mitigates against reducing the sanitation backlog.

## Implications of research findings for the long term sustainability of VIPs

South Africa's national sanitation programme, and associated VIP toilet planning and design, was heavily shaped by the 1996 draft White Paper on Household Sanitation. That approach was formulated at a time when there was very limited local government capacity in many parts of the country. The programme was premised on assisting households to build their own toilets, and government was not seen as having a role to play in VIP toilet maintenance beyond construction; toilet owners and users would build new toilets for themselves as required.

South Africa's sanitation programme is now essentially in supply-driven mode, with a target to provide sanitation facilities for all by the year 2010. Moreover, following the introduction of the policy of free basic water in 2001, government has expanded the scope of free basic services to the poor from provision of 6 Kl water per family per month, to include at least a VIP toilet, a basic amount of energy provision and a solid waste refuse removal service.

Free basic sanitation, as defined in the 2003 Strategic Framework for Water Services, also includes the operation and maintenance of the sanitation service. This implies that ongoing access to a usable toilet, alternatively a pit emptying service, is a part of government's commitment to free basic sanitation.

It is imperative that the design of VIP toilets enables government to honour this commitment.

Construction of a heavy permanent single pit VIP structure, with access to the pit only through the pedestal, makes it extremely difficult and expensive to desludge the pit. This design should be discouraged.

Yet toilet designs which permit access to the pit to enable emptying has been given very little attention.

If manual emptying is the only method that is practically and economically possible, then pits should be provided with at least two removable slabs.

Moreover, to safeguard the health and safety of workers tasked with removing sludge from pits, the required pit volumes should be achieved by increasing the pit area rather than the pit depth, as it is difficult to empty a pit deeper than 1.5 metres manually without the worker having to get into the pit.

The disposal of pit sludge by conveying it to waste water treatment works has been found to be onerous and uneconomical, both from a transport and waste handling point of view. A simpler, more economical and probably more beneficial option for low density settlements appearsto be the burial of the pit sludge