PILOTING AND TESTING THE POUR FLUSH LATRINE TECHNOLOGY FOR ITS APPLICABILITY IN SOUTH AFRICA

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Background

The constitution of South Africa mandates that all South Africans should have access to decent housing and an environment which does not threaten their health and safety. The provision of Free Basic Services has become the responsibility of municipalities, with the Department of Water Affairs (DWA) responsible for policy and oversight with regard to water and sanitation.

Ventilated Improved Pit latrines (VIPs) have been accepted as the sanitation system which represents the minimum level of service. The VIP is a robust technology which provides adequate sanitation in areas which are not serviced – and in some cases cannot be serviced - with waterborne sewerage, such as in sparsely populated rural areas or densely populated informal urban areas. There are, however, two arguments against the government's choice of this technology. Firstly, in the South African context the perception of waterborne sewerage as having higher status results in many communities seeing it as a symbol of political equality to which they aspire, resulting in dissatisfaction with dry sanitation systems. Secondly, when VIP pits gets full, municipalities are faced with a serious problem. The sludge that accumulates in VIP is typically dry and full of rubbish and cannot be emptied with the vacuum tankers that municipalities rely on to service the septic tanks of standard waterborne on-site sanitation systems. Many pits ultimately have to be emptied manually, a job that is not only messy and unpleasant but also dangerous as sludge typically contains a range of infectious human pathogens. Over 85% of the approximately 2 million VIPs built in the last 15 years are now older than 5 years, and with municipalities reporting that 82% of VIPs require emptying after 5-8 years they may soon be faced with a situation where the gains achieved through basic sanitation delivery are reversed: if pits reach capacity and are not emptied, households will effectively revert to being without sanitation.

An on-site sanitation option is needed which addresses the aspirations of many South Africans for a flush toilet while overcoming the logistical challenges involved with standard sewerage systems, while working responsibly within the limits of South Africa's water resources. An on-site flush system using a low volume of water would also produce sludge with a higher moisture content and lower solid waste content than VIP sludge typically contains, enabling it to be removed with standard vacuum technologies. A sanitation system which meets these criteria could interface with a range of beneficial sludge disposal options that do not involve treatment at a standard waste water treatment works.

Project scope

This project investigated the potential for modifying the pour flush design, which is used widely in Asia, to meet the needs of the South African context. The development and application of pour flush systems in Asia was studied. Three case studies were conducted to investigate the experience of South Africans with low flush systems in the past and related technologies were surveyed. A prototype was developed and tested after which the technology was piloted in twenty homes for usage periods of up to eighteen months. The systems were monitored over the course of the project and performance and user experience were assessed at the end of the project.

Methodology

Development of a prototype pedestal was based on key design principles used in the Asian model but with consideration of two critical differences: South African users are generally accustomed to using a pedestal rather than a squat toilet and South African users use toilet paper or newspaper for anal cleansing, rather than water as is standard in Asia. Therefore, for a design to stand a reasonable chance of success in South Africa, it would need to look as much like the standard flush toilet idealized by most dry system users who make up the bulk of the population which might benefit from a pour flush toilet, and it would need to be robust enough to cope with newspaper without blocking or requiring considerably more water than the 1-2 litres used for flushing Asian systems. A prototype was manufactured from fibreglass and tested using a standard protocol for full flush toilets while limiting the flush to 1-2 litres. The toilet performed well at 1 litre with toilet paper, while the addition of newspaper sometimes necessitated a second flush. Two test toilets were installed and monitored weekly for the first month and monthly thereafter. When they had performed without any difficulties for three months, construction began on additional units for piloting. Over the course of a year, 18 additional units were built in four communities in the uMsunduzi and uMgungundlovu municipalities. In total, 10 dry systems (6 VIPs and 4 home built latrines) and 9 HS low flush systems were converted to pour flush systems. One toilet was built for a new church building that had no former sanitation. Eleven systems were installed in outdoor structures and 9 were installed inside homes. Sewers equipped with a rodding eye were laid leading to two 1 m x 0.8 m pits lined with cement blocks with open joints. Care of the toilets was discussed with users and an educational poster was mounted on the door of each loo. Each household was provided with a jug and bucket for flushing. Pit filling rates were investigated at the end of the study and householders were surveyed regarding their experience, behaviours and attitudes with regard to the pour flush.

Key findings

The following key findings have come out of this study:

- **South African experience with low flush systems.** User perceptions expressed during the case studies conducted in this study with the DSA and Hungerford Schroeder low flush systems indicated that users perceived a number of problems with their systems. While some experimental aspects of the design of these systems may have led to operational problems over time, there is clearly a complex relationship between a number of factors which contribute to the success or failure of a system: system design, correct installation, availability of replacement parts, user behaviour and user attitudes – which can be influenced to a large extent by political and social dynamics. For a system to succeed in the South African context, it needs to address the needs of users for political equality (sometimes symbolized by a flush toilet) and political agency in service delivery, accommodate the cultural, social and economic needs of users (e.g. privacy, preference to keep defecation out of the house, access to toilet paper) and interface with sanitation management at the municipal level in terms of ensuring that soak pits will be emptied and that replacement parts are available.

- **Design.** The pour flush system developed in this study has proven successful over the first 18 months of testing. To date, only one blockage has been experienced in any of the 20 systems, and this was caused by a child flushing a plastic bag down the toilet. The one litre flush has proved adequate for typical situations, with a two litre flush sometimes used where there is a particularly long sewer leading to the soak pit. Despite the fact that there is no water sitting in the pan of the pour flush pedestal as there is with a standard pedestal, the pour flush toilets did not become soiled quickly. Reported frequency of cleaning ranged widely but when unannounced visits were made to homes toilets typically appeared clean. Some users did report that when children failed to pour flush after defecating the toilet became dirty quickly and was more difficult to clean.

- **User satisfaction** has been high and visitors to the homes where the technology was piloted expressed an interest in the pour flush model. Responses indicate that the pour flush system adequately addresses the wish of many dry sanitation users for a flush toilet, with the political, social and logistical considerations involved. Some users expressed a strong preference for locating the toilet outside due to their homes being too small to afford privacy or due to experiences with low flush systems in the past having an unpleasant smell. Some have expressed a willingness to pay in order to have their existing systems replaced with pour flush systems.

- **Life span.** Measurements of sludge depth were taken for seven pits. The pits were found to be filling at a rate ranging from 114 litres per year to 392 litres per year. When calculated based on the number of householders, filling rates ranged from 26 litres per person per year to 57 litres per person per year, with a median filling rate of 35 litres per person per year. Considering degradation and leaching over time, this indicates a probable life span of approximately 5 years before the pits need to be emptied. The sludge to date appears to be of a consistency which could be extracted by vacuum.

- **Newspaper.** The toilet proved robust enough for newspaper to be flushed without blocking the system during testing. While all households were provided with an initial pack of toilet paper and encouraged to use toilet paper if possible, it was also explained to householders how to flush with newspaper if necessary. Two households have begun to use newspaper without difficulty. Estimates of toilet paper usage range from 1 to 4 rolls per person per month at a price of R0.75-R2 per roll, although it appears that typically a household will purchase a pack of 10 rolls for R10 at the beginning of the month and use newspaper once it has run out.

- **Cost.** This technology is considerably less costly than installing a full flush toilet connected to a sewer or a standard septic tank. In addition, it is not dependent on a piped water supply and can be used even if the water supply is cut off occasionally, as a small amount of water is required and greywater can be used.

- **Rubbish.** All respondents indicated that they do not use the toilet for disposal of any other waste. Some personal items were observed in some pits a year after construction, however, in a community that has no reliable rubbish collection. The presence of waste in the pit could present difficulties when the pit needs to be emptied.

Conclusions

The success of the pour flush model designed and piloted in this project indicates that it may provide a viable option for municipalities under pressure to provide waterborne sanitation where laying sewers is not feasible or affordable, as well as for dissatisfied householders who would like to bridge the gap between dry on-site systems such as VIP toilets and full waterborne sanitation. In addition, it provides a sanitation model in which scarce water resources are used responsibly and sustainably, pointing a way forward for changes in standard sanitation which currently relies on freely available water.

This pour flush technology is ready to be taken to scale by municipalities or applied on a household by household basis. However, the pedestals used in this study were manufactured from fibreglass, which is costly. Producing pedestals from ceramic or injection moulding would enable the pour flush system to be made available at costs comparable to a VIP. In addition, it is essential that wherever pour flush systems are installed, pedestals and other parts are made available to local hardware shops and plumbers to ensure that systems can be repaired over time. Where a household has space inside the house for a toilet and is willing to have an indoor toilet, the pour flush can be installed indoors, saving on the cost of building a structure to house the pedestal. Alternative, if the household already has a VIP toilet and prefers to have the pour flush toilet located outside, the pedestal can be removed and a new pit constructed next to the structure, reducing the costs of building a new structure.

While the pour flush technology may not be suitable for a public toilet facility because of the likelihood of users failing to flush and replace flushing water, further design development could explore the adaptation of the technology to include a cistern and mechanical flush.

Pour flush technology shows the potential for overcoming one of the thorniest challenges encountered with VIP systems: removing the sludge from full pits. While VIP sludge is often too dry and contains too much rubbish to be removed with a vacuum tanker, the pour flush system is far more conducive to vacuum removal because sludge contains less rubbish and has a higher moisture content. However, if municipalities do not collect solid waste, it can be expected that householders will feel they have no option but to dispose of some solid waste into the pour flush system, either by flushing the waste down the toilet or by accessing the pit directly. A reliable rubbish collection programme is therefore vital in order to ensure that the full benefits are gained from the pour flush system.

As many households in South Africa are unable to afford toilet paper, the ability of the pour flush system to accommodate newspaper makes this a technology which municipalities could roll out even to poor communities and which poor families could opt for with a one-time expense of upgrading their system but without incurring a long-term expense of toilet paper which they may not be able to sustain.

While the sludge in pour flush systems in general will be wetter than the sludge in VIP pits, which also facilitates removal by vacuum technologies, there is much still to be understood about the changes in sludge in a pour flush pit over time. Changes in the moisture content over time – particularly if sludge is left in one pit while a second pit is in use – and the impact of drainage from the pit on the surrounding soil need to be monitored over the lifetime of these first pour flush pits to determine the environmental impact and the management implications of the sludge that is produced.

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Background

The introduction of a pour flush toilet using 1 to 2 litres to flush and with an on-site leach pit would represent a valuable addition to the range of sanitation options available in South Africa. It would also potentially offer solutions to a number of political and management issues that have arisen with the provision of VIP toilets. In particular, there is a strong desire on the part of many South Africans who currently have dry on-site sanitation systems – typically VIPs – to have waterborne sanitation, which represents political equality, higher status and greater convenience. However, providing waterborne sewerage to all homes in South Africa is neither a sustainable option for a water scarce nation nor a feasible option considering the long distances to and between homes in rural areas and, in contrast, the lack of space in dense informal urban settlements. An on-site sanitation system which provides the benefits associated with a flush technology while avoiding the logistical difficulties of sewering could address these needs.

In Asia, the pour flush model has become a standard sanitation option. A small amount of water – 1 to 3 litres, compared with the 4 to12 litres required by standard flush systems – is poured by hand into the pan to flush excreta past a water seal. Greywater can be used for flushing, so that water consumption is not necessarily increased above what it was with dry sanitation. Because unpleasant smells are sealed off from the pan by the water seal, the pedestal can be installed indoors if desired. Sludge may be contained on-site in a soak pit or biogas digestor, or piped away from the site through simplified sewage to a decentralized treatment plant.

A few obstacles stand in the way of implementing the Asian pour flush model in the South African context. The Asian toilet is designed for squatting and does not have a pedestal. South African users, on the other hand, are generally accustomed to sitting on a pedestal rather than squatting. In addition, while in Asia water is typically used for anal cleansing, South Africans generally use a dry material – toilet paper if they can afford it, newspaper or other materials if they cannot. A pour flush system designed for South African users must therefore include a pedestal and be robust enough to handle toilet paper and newspaper.

In this report “pour flush” refers to a system designed to be flushed by water poured into the pan by hand, pushing material through a water seal. When the term “low flush” is used, it refers to a system designed with a mechanical flush which is designed to dispense water from the cistern around the pan, pulling material out of the pan. Low flush systems do not always have water seals. Both pour flush and low flush systems may use a low volume flush (1-2 litres) and if the water supply is interrupted or the flushing mechanism of a low flush system breaks, it can be flushed by pouring water into the pan by hand. However a considerably greater amount of water is typically needed to flush a low flush system by hand because it is designed to flush on the principle of a vortex pulling the material through, rather than through the push created by a dumping action.

Low flush pedestal designs have been installed in some communities in South Africa in the past. A survey of three communities with low flush toilets was conducted for this project, in which it was found that user satisfaction generally is not high. Key factors contributing to user dissatisfaction were the failure of design elements which did not stand up to user behaviour over time and inferior parts or unavailability of replacement parts.

Aims

The aims of this project were as follows:

- Establish what is the current best practice state for pour flush sanitation in South East Asia, where it is widely applied

- Establish which existing South African sanitation technologies most closely approximate pour flush and the operational history of these technologies

- Produce a design for a South African pour flush latrine

- Test the pour flush design in a suitable community. Monitor its technical, operational and social viability

- Establish linkages between pour flush technology and water supply /greywater disposal

Methodology

In order to fulfil these aims, the following activities were carried out:

- A literature review of pour flush technology used across the world was conducted. An investigation into related technologies in use in South Africa was made. Case studies were conducted in three communities where *low flush* systems are in use.

- A pour flush system with a pedestal was designed based on the Asian design. The design was tested at 2 homes. The technology proved successful over the first four months of use, after which 18 more units were constructed at homes where householders had previously used dry systems or low flush systems.

- The 20 units were monitored for up to a year after construction after which the technical, operational and social success of the systems was evaluated.

Results

This document reports on the activities identified above. Chapter 2 reviews existing pour flush and low volume mechanical flush designs used internationally and in South Africa. Chapter 3 explores the experience of users of low flush systems in South Africa in terms of operation of the systems, user behaviour and user attitudes. Chapter 4 presents the development of a pour flush prototype appropriate to the South African context, including design, testing, piloting and evaluation of the new technology. Chapter 5 explores management options for pour flush systems including methods for pit emptying and options for the beneficial use or disposal of sludge.

2 EXISTING ON-SITE LOW VOLUME FLUSH LATRINE DESIGNS

2.1 Key design elements

On site flush systems using a low volume of water which have been developed to date vary in terms of a number of design elements. The user may sit on a pedestal or squat on a squat plate. The system may use a mechanical flusher, with water dispensed from a cistern which is filled by hand or from a piped water supply, or it may be pour flushed by hand. Flushing mechanisms, materials and aesthetic aspects of pedestals vary. Mechanisms for separating the user from their excreta vary and a number of different arrangements between the pedestal and the pit have been used. Systems may attempt to address the way the pit fills and how sludge is removed by the way in which liquids are separated or allowed to leach from the pit and whether sludge is allowed to dewater before it is removed or how it is encouraged to degrade while moving through the system. Some of these design aspects are highlighted below.

2.1.1 Water seal

Systems using a low volume of water for flushing usually incorporate a water seal of some sort which prevents odours and insects from coming up from the pit through the pedestal. A water seal is usually created with either a U bend pipe or a goose neck, where water is trapped as it is flushed. Some designs, however, rely on the effluent itself as a water seal or do not have a water seal at all but simply provide a vent pipe for gases to escape from the pit.

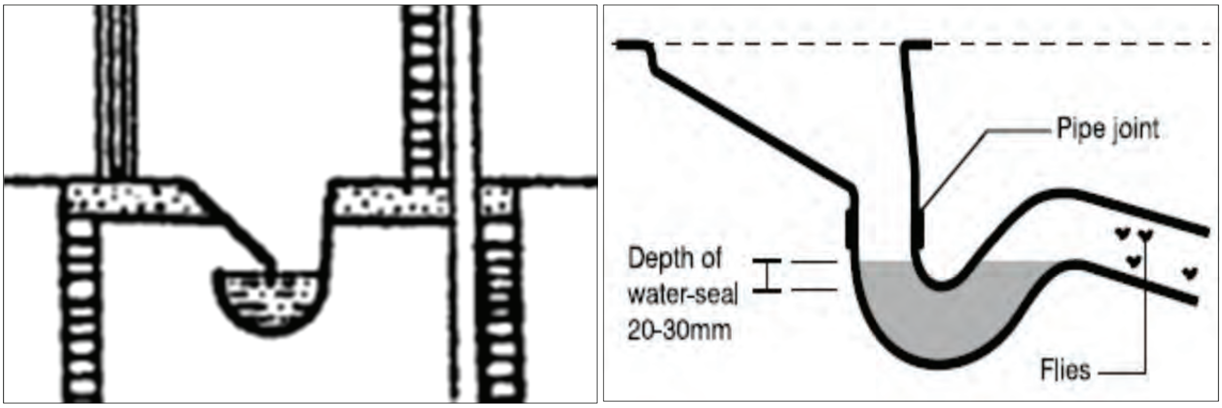

Figure 2.1 Goose neck (left) and reverse U bend (right) water seals (WHO)

2.1.2 Separation of urine and faeces

The principle of urine diversion can be incorporated into the design pour flush systems, allowing users to use water only for flushing faecal matter. As urine contains approximately 80% of the nitrogen, 55% of the phosphorus and 60% of the potassium in domestic wastewater (GTZ, 2006) and does not contain pathogens, it can be used safely for agriculture without treatment, enhancing the nutrient value of food and saving on the cost of fertiliser.

2.1.3 Pit/pedestal arrangement

The simplest and most inexpensive arrangement for pedestal and pit is to place the pedestal directly over the pit. This allows for a simple conversion of a VIP toilet to a pour flush toilet and permits blockages to be easily cleared. However if a user is to sit directly above the pit it is critical that the pit is lined to ensure adequate stability and that a strong slab is laid, as there have been cases of pits or slabs collapsing and users drowning in excreta. Emptying the pit with this arrangement can be problematic, however. The latrine will either have to be dismantled or accessed from outside through a hole in the wall of the pit.

Another option which overcomes this problem is for the pit to be offset from the pedestal, allowing the pedestal to be installed inside the house with the pit placed outside and covered with a concrete slab. This may be safer for users, as well as more convenient.

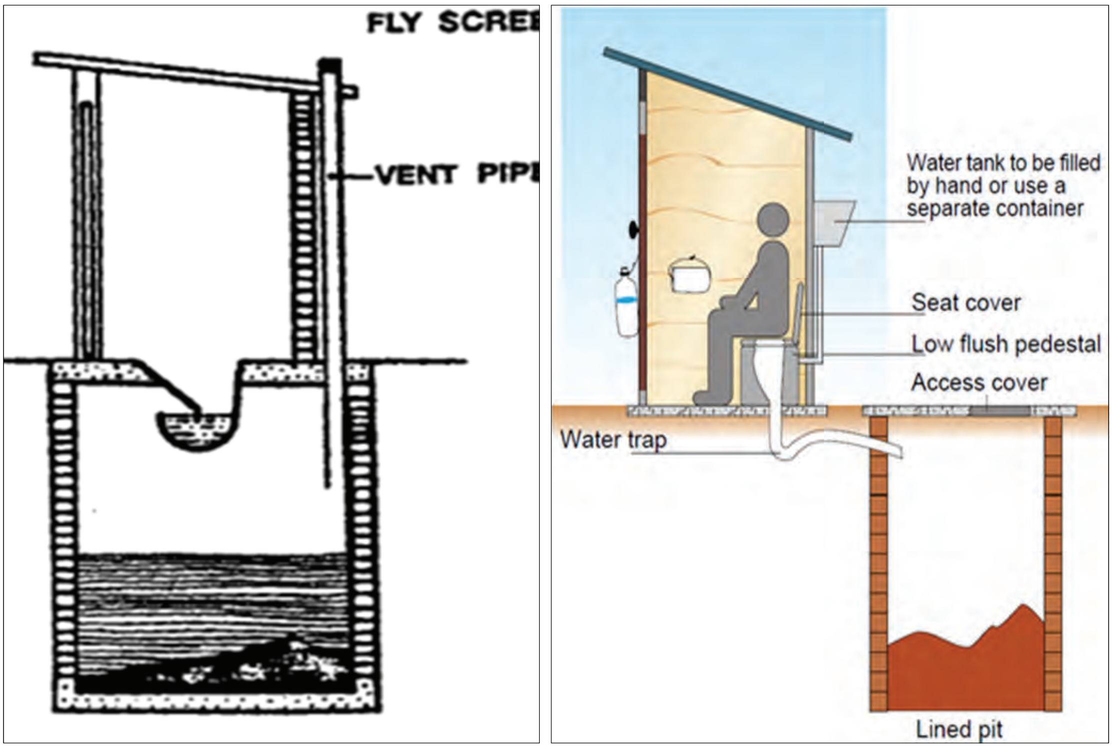

Figure 2.2 Pit directly under pedestal (left, WHO) or off-set from pit (right, DWAF)

2.1.4 Pit design

Single / double pits

A twin pit pour flush latrine is an offset design which incorporates a junction box close to the outlet from the pedestal. A Y configuration allows one pit to be blocked off while the other is used. The advantage of using two pits is that the volume of the sludge in the pit that is not in use will reduce through degradation and drainage. When the contents are removed, the volume of the sludge will be less. Using two pits could allow for a smaller pit size which then facilitates easier emptying. Twin pits should be sealed off from each other or separated by an adequate distance to prevent cross contamination. One drawback of using two pits is that the junction box increases the chance of blockages over the single pit design, and switching the pits requires management by users.

Sludge that has been left in an unused pit will be drier and denser and may be difficult to remove with a vacuum-based technology. Design of pits should be done in conjunction with the planning and adoption of an emptying programme to ensure that emptying frequency, emptying technology and disposal options are optimised.

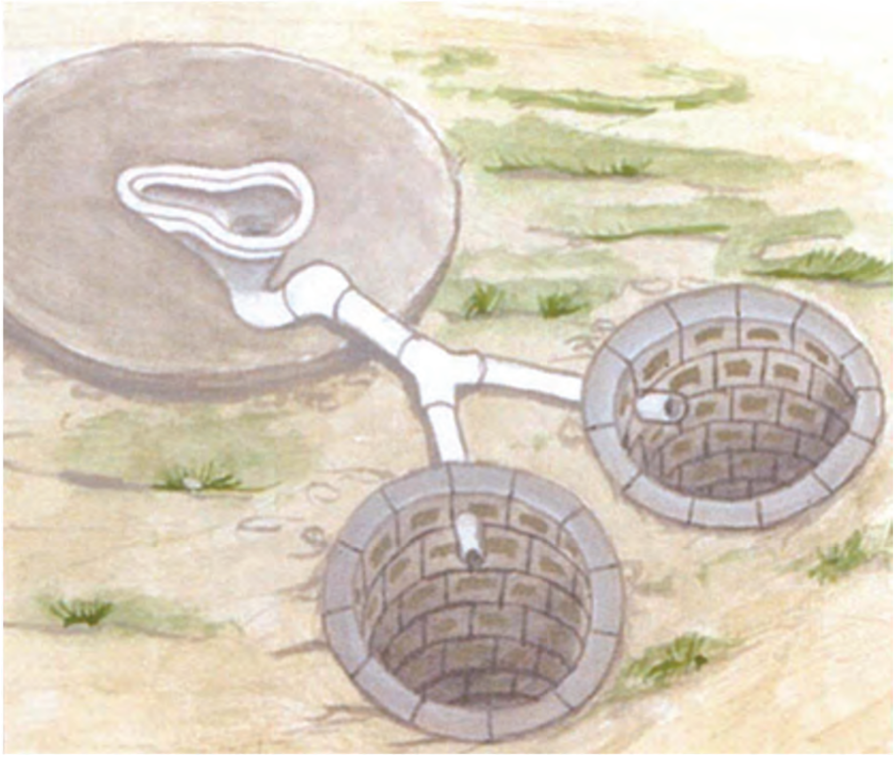

Figure 2.3 Twin pit pour flush design (Obika, 2004)

Coffey/UN-HABITAT innovation

Manus Coffey, an international expert working with UN-HABITAT in faecal sludge management, has proposed a pit design specifically to serve a pour flush system (Coffey, 2006). A precast tank would be constructed directly under the pedestal with a capacity designed to hold approximately two years of waste (1 m^3). Servicing the pit on a two year cycle would allow sludge to be removed before it has become compacted. In addition, a suction pipe would be built in to the tank, leading from the bottom of the tank to a valve outside the latrine which would serve as a connection for the suction hose of a vacuum tanker. This would prevent the contamination associated with plunging the hose into the pit contents and ensure suction from the bottom of the tank so that the capacity of the pit is not gradually reduced by a dense layer of sludge which cannot be removed.

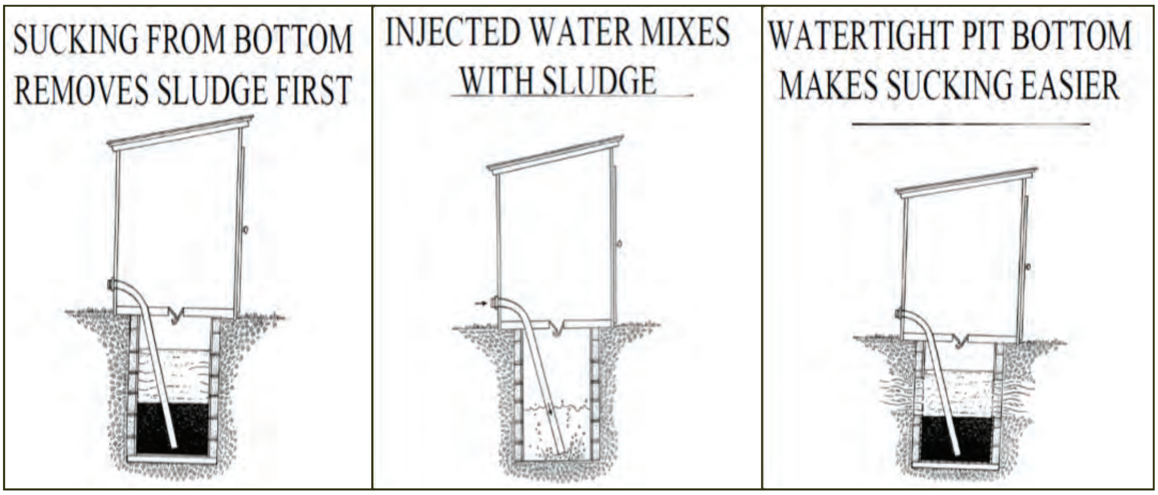

Figure 2.4 Manus Coffey's pour flush vault design (Coffey, 2006)

UN HABITAT established an expert group, which began to meet in 2008, to investigate this design. In testing, it was found that the addition of a small amount of water from a pressurized Vacutug tank through the built in pipe resulted in a dramatic decrease in viscosity, allowing even dense sludges to be removed with a vacuum tanker (Coffey, pers. comm., 2009).

2.2 Origin and development of pour flush technology in Asia

The first known pour flush design with a water seal is attributed to Governor Sawadi Mahagayi of Thailand, who invented his "goose-neck" toilet in 1924 (Black and Fawcett, 2008). The squatting plate was located directly over the pit.

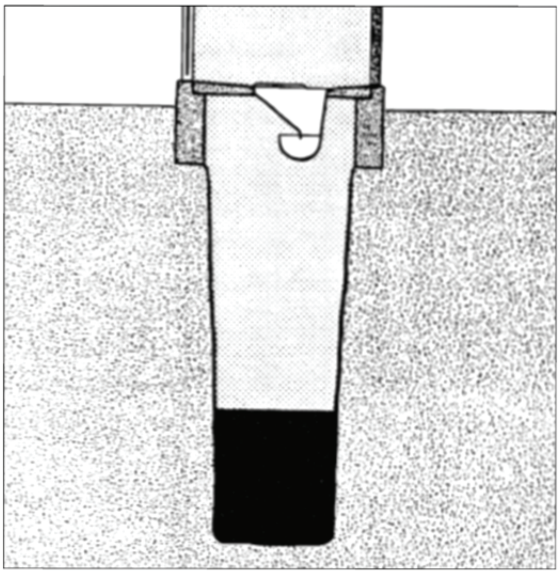

Figure 2.5 The "goose-neck" type of pour flush latrine first used in Thailand in 1924 (Mara, 1985)

Independently, a pour flush water seal latrine was developed in the mid-1940s at the All-India Institute of Hygiene and Public Health (AIIHPH) in Calcutta (Black and Fawcett, 2008). The pour flush has subsequently become the standard for basic sanitation in India. The technical note on pour flush latrines produced by Duncan Mara (1985) gives a good idea of the standard Asian pour flush latrine as built during the 1980s.

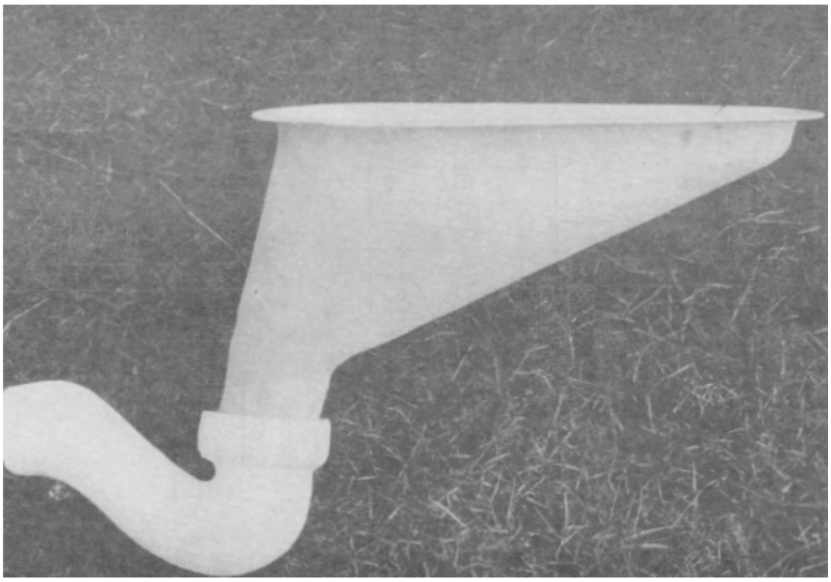

Figure 2.6 The standard Asian type pour flush pan and water seal (Mara, 1985)

The Asian latrine is designed for squatting, not sitting, and does not have a pedestal. The key parameters are the 25° slope of the front of the pan, and the 75-70 mm diameter of the outlet pipe.

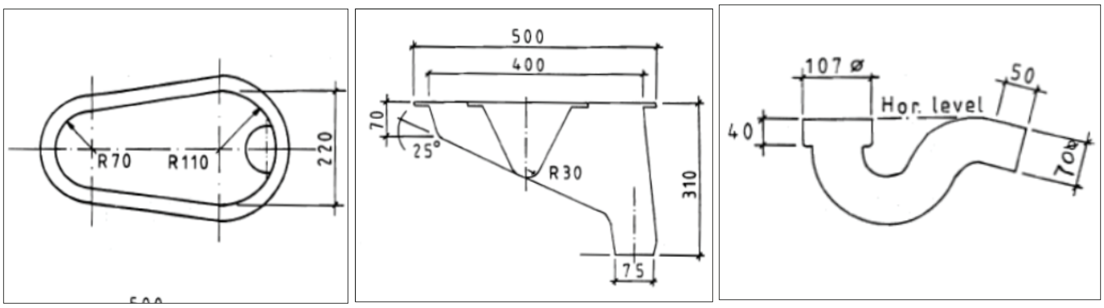

Figure 2.7 Design details for the Asian pour flush pan and water seal from Mara (1985)

Today, the Indian NGO *Sulabh International*, founded by Dr Bindeshwar Pathak in 1970, is a leader in Asian sanitation. Sulabh promotes the pour flush latrine with single or double leach pits and has built more than a million of these units in India. Figures 2.8 and 2.9 below show excerpts from Sulabh's brochure on the pour flush toilet.

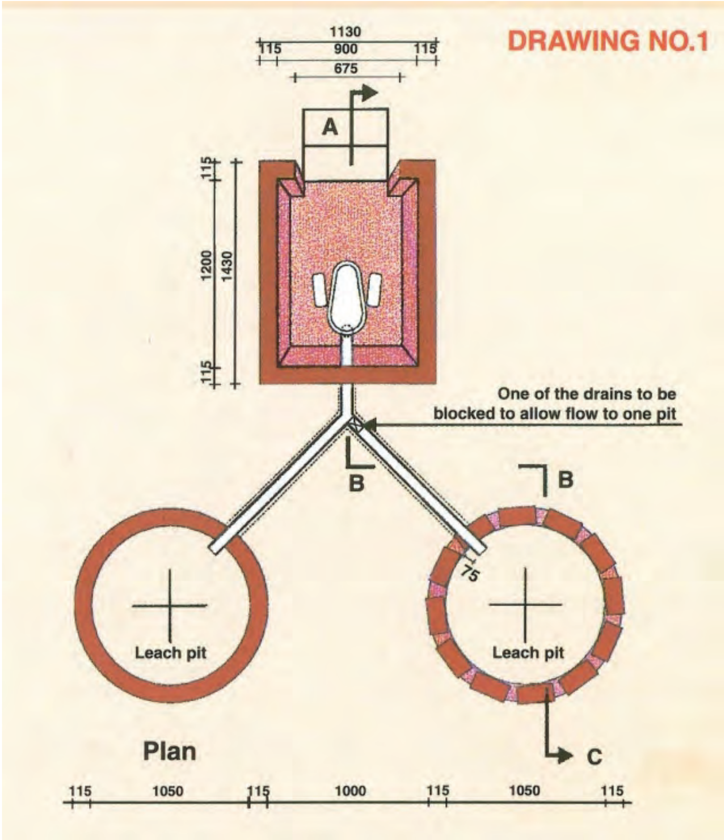

Figure 2.8 Plan view of pour flush latrine with separate soak pits (Sulabh brochure)

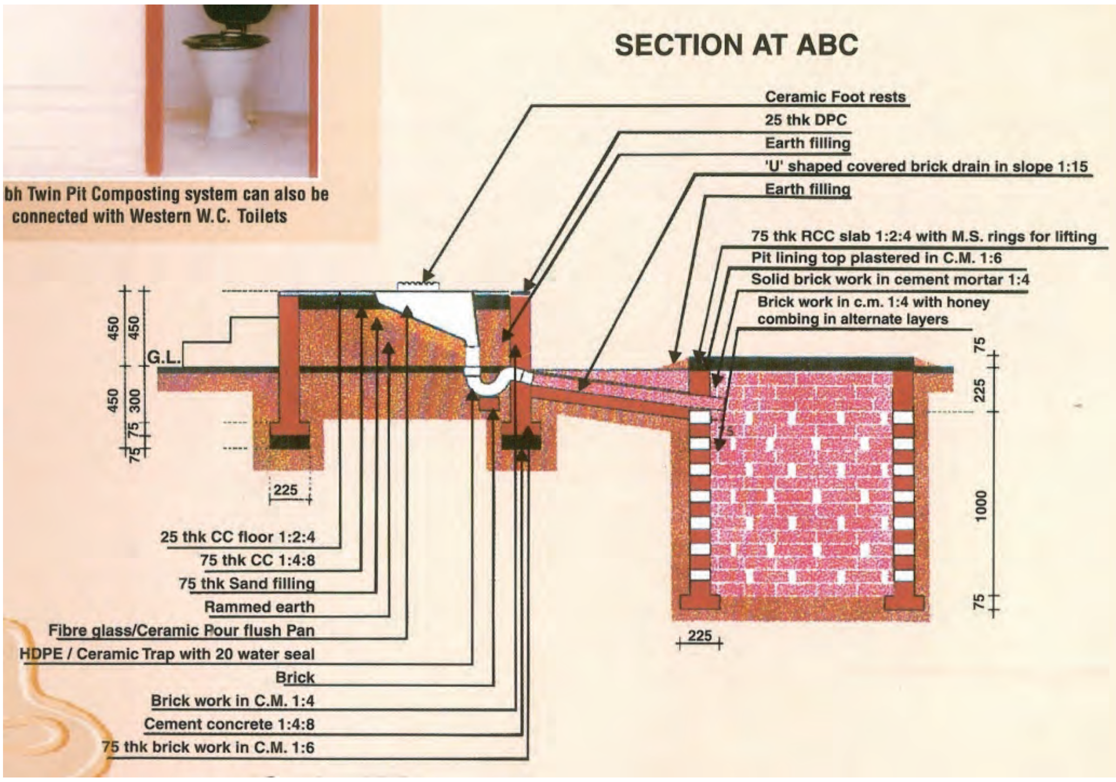

Figure 2.9 Cross section of Sulabh pour flush design (Sulabh brochure). The pan details are essentially unchanged from those shown in the 1985 Mara report.

The Indian government offers subsidies of up to 90% under its Low Cost Sanitation scheme, and estimates the cost of building a twin pit pour flush latrine at approximately 10 000 rupees (ZAR 1 500) (WaterAid, 2008). The drive to eliminate dry sanitation arises from the government's commitment to end manual bucket and pit emptying. While the pour flush model has appeared generally to be a successful sanitation operation across the country, some problems have been noted, however. Some have fallen out of use due to a shortage of water for flushing, others have filled rapidly due to a high water table (Nema, 2005). Education on how to use the systems has not always been adequate and in some communities both pits of a twin pit system were found to be in use simultaneously (WSP, 2000).

The Indian design has also been used in community sanitation blocks, with several toilets sharing a pair of pits. Larger pits, with a diameter and depth of up to 2.7 m, were recommended (Roy et al, 1985). While the community ablution blocks built by Sulabh International are often cited as success stories (Mojumdar, 2008), there have been some cases where the model proved problematic (Nadkarni, 2009).

In 2002, WaterAid introduced a urine diverting pour flush toilet, called the Wet Ecosan, to Nepal (WaterAid, 2008). Water used for anal cleansing and flushing enters the pan and passes through a 110 mm pipe to twin pits. Urine is collected in 20-30 litre plastic containers. While users were initially resistant to the idea of using excreta for agriculture, the use of urine was accepted and has resulted in enhanced growth of vegetables grown in soil to which it was applied. The Wet Ecosan systems cost approximately 16 500NPR (ZAR 1 600).

Figure 2.10 Wet Ecosan system in Parsa, Nepal (ENHPO in WaterAid, 2008)

Figure 2.11 Double pit pour flush latrine construction in Sri Lanka (Rebecca Scott, WEDC)

Pour flush latrines with pedestals have been developed successfully in the Caribbean, where toilet tissue is used for anal cleansing (Scott, 2005). In Australia, pour flush latrines are used for indigenous settlements in remote areas (Anda et al, 2001). These are built with a septic tank directly underneath the pedestal and a reversed (forward facing) U bend.

Figure 2.12 Australian pour flush pedestal (RADG, 2003)

2.3 Introduction of low flush technology to South Africa

While in Asia users prefer a squat toilet and use water for anal cleansing, in South Africa users are accustomed to a pedestal and using a dry material – typically toilet paper or newspaper - for anal cleansing. While no pour flush systems have been used in South Africa to date, some low flush designs have been implemented which were investigated for this project.

❖ Calcamite low flush systems

During the late 1980s, Calcamite Sanitary Services (Pty) Ltd began to develop a low flush on-site sanitation system which could be upgraded to a low volume mechanical flush model with water dispensed from a cistern. In 1994 the low flush model was awarded an Agrement certificate (G. Pryce-Lewis, pers. comm., 2011)

Low flush ventilated improved lined pit (VILP)

The toilet had a purpose-made pan of vitreous china. Customer satisfaction with the aesthetics was reported to be high as the pedestal looked like the pedestal of a standard flush toilet. Water wa poured into the pan and discharged through a 110 mm diameter PVC pipe directly into the digester or other waste collection system. The design did not include a water seal as pour flush systems do, but a vent pipe at the back of the digester tank reduced unpleasant smells coming up through the pan.

Calcamite designed the system to discharge into a rotary-moulded, 55kg polyethylene digester tank with a total volume of 1548 litres and a liquid capacity of 1463 litres. Optional lid extensions can increase the tank volume. The digester facilitates the separation of solids (both floating scum and settled sludge) from the liquid fraction of the waste so that the effluent can be dealt with in a sub-soil percolation system or transported by sewer to a treatment facility.

It was observed that when the system was in use heat generated by degradation of excreta in the tank causes beads of condensation to form in the discharge pipe. This keeps the pipe wet and facilitates the discharge of excreta from the pan to the digestor (G. Pryce-Lewis, pers. comm., 2011).

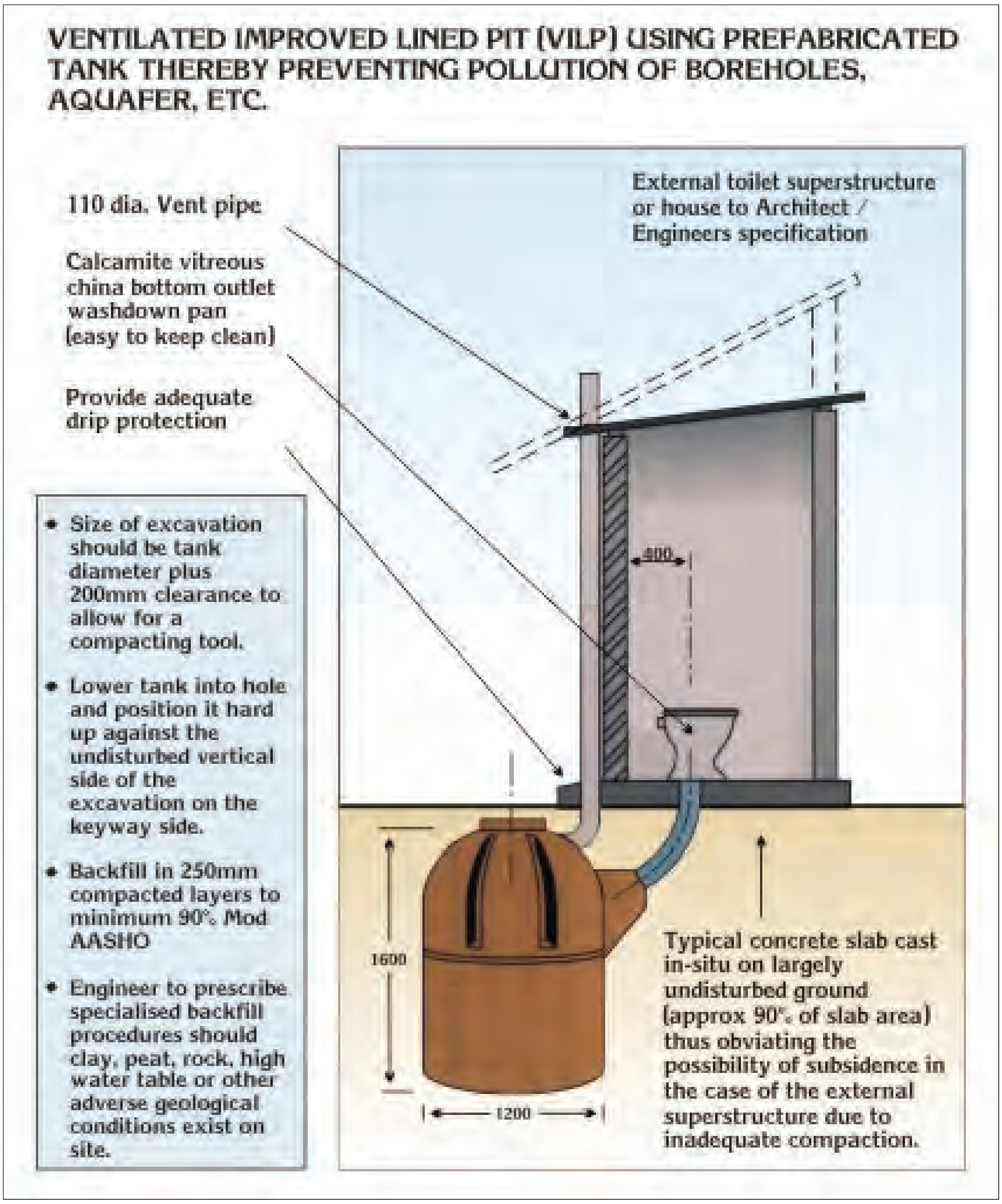

Figure 2.13 Calcamite low flush model (Calcamite)

Low flush upgrade

Calcamite developed a simple upgrade of the low flush system by adding a one litre flush cistern manufactured from polyethylene. The water was released directly into the pan in a dumping action, pushing excreta down the discharge pipe, rather than by distributing water around the pan to create a vortex to suck the contents out of the pan. A 9 litre top up tank was mounted above a 600 mℓ tank. When the flushing mechanism was released, the lower tank was refilled from the reserve tank. The top up tank could be filled manually or connected to a water mains. The cistern used a standard operating handle and valve mechanism.

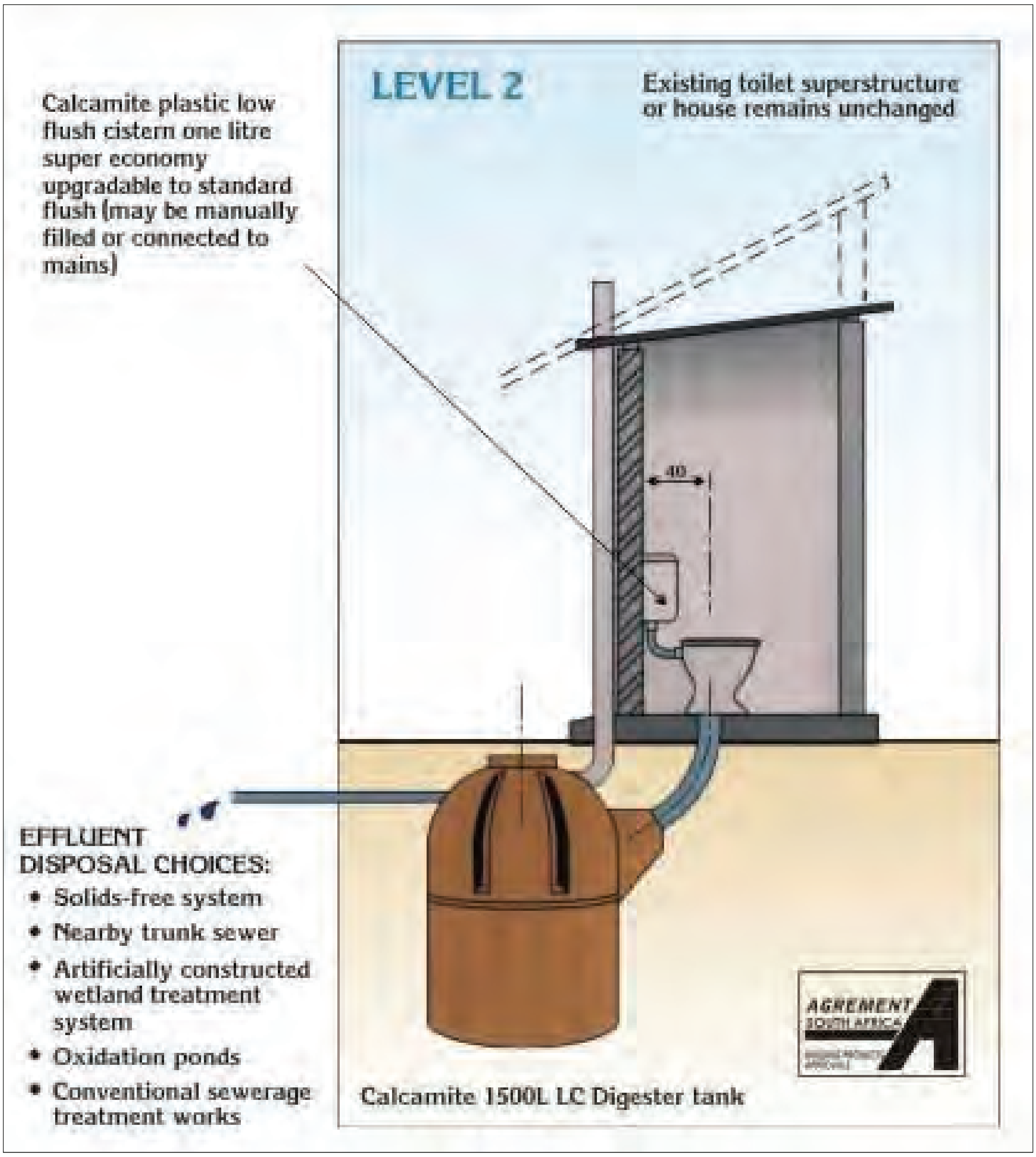

Figure 2.14 Calcamite low flush upgrade (Calcamite)

Initially the company spent a great deal of time marketing the models to local government and approximately 65000 units were installed in Gauteng and the Eastern Cape. Finding municipalities generally unwilling to consider sanitation options other than the standard VIP dry system (due to cost considerations), the company eventually stopped marketing these models and has not installed any either model during the past decade (G. Pryce-Lewis, pers. comm., 2011).

❖ Hungerford Schroeder (HS) model

The HS system has a 13 litre cistern which dispenses 1 litre of water around the edge of the pan when flushed. In the original HS design, the one litre of water plus excreta sitting on the tipping tray in the bottom of the pan is then tipped into the liquefying tank below the toilet, displacing 1 litre of the tank's contents through a pipe into a small drum which contains a strainer to catch foreign matter, from which it is displaced into a soak pit. The designer believed that after being liquefied in the liquefier the sludge could be completely digested in the soak pit, resulting in no sludge build up.

Figure 2.15 Hungerford Schroeder toilet

The HS system was installed in various communities around KwaZulu-Natal. In some cases the digestor was modified, and a number of different soak pit designs were used. These variations are discussed in the case studies in Chapter 3.

❖ Direct Sanitation Application (DSA)

Bezuidenhout designed the Direct Sanitation Application toilet in 2006, having worked with the HS model and travelled extensively to Asia and South America to investigate on-site sanitation options. He concluded that anaerobic toilets inevitably have an offensive odour, and accordingly worked to develop a design which maximises oxygenation in order to promote strong aerobic activity (E. Bezuidenhout, pers. comm., 2010).

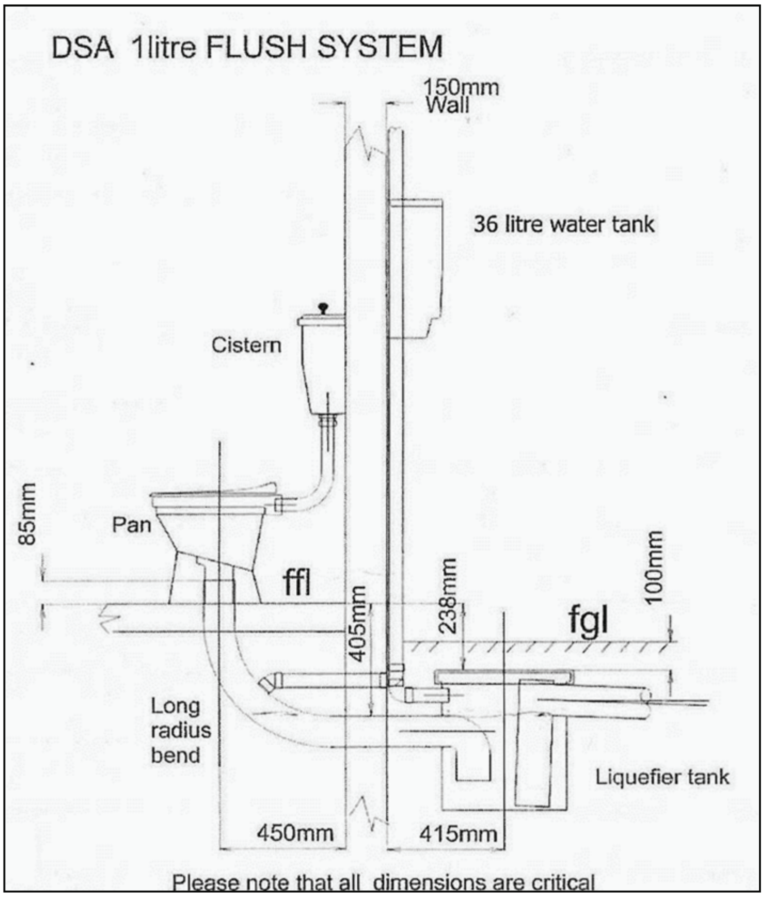

Figure 2.16 DSA low flush system (E. Bezuidenhout)

A 36 litre reserve water tank is installed on the outside wall of the toilet which can then be filled from the closest water source. This supplies the cistern inside which holds 9 litres, allowing 45 flushes before the system must be refilled. A pull knob dispenses 1 litre of water from the cistern around the pan. Contents are washed down a 110 mm long radius bend pipe out of the house into a 30 litre liquefier tank. A 50 mm pipe vents the toilet from just above the water seal on the toilet side of the liquefier tank. The role of the liquefier is to break down excreta and toilet paper into a homogenous liquid and promote the start of digestion. Each new flush displaces 1 litre from the bottom of the tank through the 110 mm pipe to the soak pit. The 1100 mm wide by 1900 mm long by 500 mm deep soak pit is designed to allow the sludge to interact with aerobic bacteria in the aerated layers of the soil with the intention that waste will be consumed in a short space of time resulting in no build-up of sludge (E. Bezuidenhout., pers. comm., 2010). The openings to the liquefier are to be sealed with silicone and the liquefier lid should be covered with soil. A smaller round cover is fitted within the concrete soak pit cover to give householders access to the pit if needed.

Figure 2.17 DSA reserve tank, cistern and pedestal

Approximately 7 500 DSA units have been installed in South Africa, with further installations reported to be underway in Cape Town, Zimbabwe, Tanzania and Haiti (E. Bezuidenhout., pers. comm., 2010).

3 EVALUATION OF USER EXPERIENCE WITH HUNGERFORD SCHROEDER AND DSA LOW FLUSH SYSTEMS SOUTH AFRICA

In order to investigate user experience with low flush systems in South Africa, case studies were conducted in three communities where several hundred low flush toilets have been in use for some time. Two of these had the Hungerford Schroeder model, while the third had the DSA. Twenty-five to thirty-one households were surveyed in each community, with every fifth house selected wherever possible. Additional information was obtained through interviews with project managers.[1]

A survey (Appendix A) was designed in order to investigate the success of the systems over time from three perspectives:

- **0perational history of the systems as reported by users**. This explored the perspective of users regarding the functionality of different components of the system.
- User behaviour with regard to the systems. This covered the type of anal cleansing material, the amount of water used to flush, products used to clean the toilet, and disposal of solid waste or greywater into the system. It also explored defecation elsewhere than the toilet, and the role of the toilet in the household for purposes other than defecation.
- **User acceptance of the systems.** This covered attitude and changes in attitude toward the system over time, as reported by users.

3.1 Hungerford Schroeder low flush system: France, Msunduzi Municipality (Pietermaritzburg)

Approximately 4 400 Hungerford Schroeder toilets were installed during the construction of houses by the Msunduzi municipality in France, a peri-urban community, during 1998-2000. Thirty-one households were surveyed for this case study. The city's sanitation engineer explained that the HS toilet was selected primarily because as a flush technology it could be built inside the house, saving the municipality the cost of building separate structures for toilets. It was also believed to be superior to a VIP latrine.

The municipality modified the original HS design by removing the liquefier below the toilet and added an upturned elbow at the soak pit end of the sewer connection. The sewer pipe would then serve as the liquefying chamber and would create an additional water seal which would prevent unpleasant smells from coming back up through the pan from the soak pit. The soak pit was a metre deep, with no lining on the bottom and cement blocks with open joints in the walls of the pit. This modified design was used for the first 400 houses, but the municipality later discovered that the contractors had left the upturned pipe off of many of the systems, resulting in the contents passing directly to the pit with no water seal between the pit and the tipping tray. Because soil depth in some areas did not permit adequate percolation of liquid from pits into the ground, an alternative design was used for some sites with smaller pipes branched off of the main pipe in a herringbone structure to distribute liquefied sludge over a wider area rather than allowing it to accumulate at the exit from the pipe.

[1] A full report of this study can be found in *Water Research Commission Project K5/1887: Three case studies of low flush systems (2011)*.

The municipality installed a water tank on the roofs of houses with a trickle flow system that dispensed 200 litres to the household over 24 hours. The 200 litre tank became an issue because the same restriction on access to water was not placed on other communities. Some residents were also concerned that outdoor water storage was not safe because it enabled individuals outside of the family to access the water supply, introducing risks of poisoning or of magic being used against the family. There was also concern that a spiteful neighbour could turn on one's outdoor tap and let the day's water supply run out. Contractors trained during the project to access the municipal water mains then began breaking into the water network and providing direct connections to households with an outdoor standpipe. The roof tanks became obsolete in these cases and were often taken down. In other cases systems were sabotaged in order to motivate for waterborne sewerage.

3.1.1 User reports of system functioning

Respondents were asked about the functioning over various components of their toilets. The following information on the status of their systems was reported.

Table 3.1 Status of system components reported for HS toilets in France

Component	% reported working	% reported not working	% not reported
Cistern	23	58	19
Flusher	___	10	90
Tipping tray	48 (1 repaired)	29	23
Liquefier	35 (19% have had problems in the past)	6	59
Functioning	% reported no	% reported yes	% not reported
Soakpit reached capacity?	16	68	16
Experienced blockages?	13	45	42
Smells?	___	61	39

Problems which caused the greatest distress were often with the tipping tray. Some of these had broken off or stopped working, with the result that there was no seal between the user and the pit. As a result, offensive smells, and sometimes worms, were found to come up from the pit into the pan. Cisterns had frequently begun to leak or flushers stopped working, with the result that the user had to pour water either into the cistern or pan to flush. Several families had removed their cisterns due to problems with insects. Thirteen percent of those without a working flush reported that they need to flush 2 or 3 times; while those whose cistern didn't work typically used a 5 litre bucket of water to flush, with a few reporting that they had used 2 or more buckets of water to flush. Blocked pipes and full or overflowing soak pits

CHANGES SUGGESTED BY USERS

"If it can flush, that's all I want from it."

"The improvement I would like is for it to be changed!"

"Pipe the sludge away from the house so we don't smell it. We don't want the sludge in the house."

"I don't need any improvements, I just need a new toilet!"

were also problems which caused discomfort to householders.

The municipal engineer mentioned that a problem with the provision of this system was that parts were not standard or available in hardware shops, making it difficult for householders to repair their systems (M. Greatwood, pers. comm., 2010).

Figure 3.1Water tank that has been removed (left) and pan with tipping tray missing (right)

3.1.2 User behaviour

While 77% of respondents indicated that they only use toilet paper, a significant minority (19%) indicated that they also use newspaper at least some of the time. Approximately a third of users indicated that the one litre flush is adequate, a third were unsure how much they used and a third used 5 litres or more to flush. A significant minority (19%) put Jeyes Fluid into the system.

Table 3.2 Material reported entering HS system (%)						
Anal cleansing material	Toilet paper only	77	Both toilet paper and newspaper	19	No response	3
Amount per flush	I litre only	29	5 litres (bucket)	32	10 litres or more	3
Cleaning/unblocking products	Household cleaners	48	Jeyes Fluid	19	No response	42

3.1.3 User acceptance

Sixty-five percent of respondents reported that their feelings about the toilet have deteriorated over time while 16% still had the same level of satisfaction that they did originally. One respondent said that the family had never liked the design from the beginning. Thirty-two percent mentioned the unpleasant smell of the toilet as a reason for their dissatisfaction.

IMPACT OF FAILED SYSTEM ON DIGNITY AND QUALITY OF LIFE

"It's embarrassing – the minute you arrive here it's already more than enough. Even the relatives no longer spend the night because the smell is unbearable."

"It's no longer the same because I have had so many diseases because of it. The place is not healthy, as you can see."

"Konke okwaleli itoyilethi kufile!"(Every part of this toilet is dead!)

"Friends sometimes come and I feel embarrassed when they have to use the toilet and it's not working."

"We do get embarrassed because this type, it's unusual. When the person is inside you can smell [what's going on.]"

Thirteen percent commented that they believe the system poses a threat to the family's health or has already compromised it. When asked if they have to explain to visitors how to use the toilet, 26% said they did while the rest did not comment. Two respondents reported that their toilets flush unexpectedly and that they have to warn guests about this so that they will not be alarmed. Seventy percent reported that they feel embarrassed about their toilet, 10% reported they do not. Twenty-six percent said they wish the toilet could be replaced with a waterborne system (2 citing the flush toilets in a neighbouring township), while 10% expressed simply that they would like it to flush properly.

3.2 Modified Hungerford Schroeder low flush system: *KwaNzimakwe, Hibiscus Coast Municipality (Ugu)*

Hibiscus Coast Municipality (a local municipality falling under the Ugu District) installed approximately 600 Hungerford Schroeder toilets as part of a housing project in the community of KwaNzimakwe during 2002-2006. Residents opted for the HS design presented by the engineer over a VIP design (their initial request had been for waterborne sanitation which the district municipality had turned down) but once they had moved into the houses and began to use the toilets some were unhappy with the tipping tray or the material and aesthetic design of the pedestal. The DSA design was then presented to the community and approved for the remaining homes to be built.

Six hundred modified HS toilets were built during the period 2002-2005. Respondents from twenty-five households in KwaNzimakwe provided the following information:

3.2.1 User reports of system functioning

Table 3.3 Status of system components reported for HS toilets in KwaNzimakwe

Component	% reported working	% reported not working	% not reported
Cistern	48	52	0
Flusher	56	44	0
Tray	44	40	16
Liquefier tank	32	4	64
Soakpit	64	28	8
Functioning	% reported no	% reported yes	% not reported
Soakpit reached capacity?	36	52	12
Experienced blockages?	24	72	4
Smells?	24	28 (additional 32% reported occasional smell)	16

Users noted similar problems with tipping trays breaking off or not working, worms coming up the system, and flushers not working or the amount of flush water being inadequate.

Figure 3.2 Exposed soakaway and broken pipes

3.2.2 User behaviour

Respondents reported the following behaviours with regard to their low flush systems:

Table 3.4 Material reported entering modified HS system						
Anal cleansing material	Toilet paper only	92%	Both toilet paper and newspaper	8%	Other	0
Flush water	Tap water only	76%	Tap water and greywater	16%	Only greywater	8%
Amount per flush	2.5 litres or less	4%	5 litres	28%	10 litres or more	44%
Cleaning products	Household cleaners	72%	Washing powder	12%	Jeyes Fluid	4%
Disposal of other household waste						
Greywater	Outside	88%	Toilet	12%	Other	4%
Direct into soak pit	Never	88%	No response	12%		

Three households have replaced their systems completely. Some respondents reported fetching water from a dam for flushing. Reasons given for what might have caused blockages were: soak pit is too small (3), flush volume is too small (3), flushing of newspaper (1) and flushing of litter (1).Three households have extended their soak pits or built new ones because they were too small.

3.2.3 User acceptance

Seventy-six percent of respondents reported their satisfaction with the toilet has deteriorated over time while 20% are still as satisfied as they were at first; 4% never liked the toilet from the beginning. Forty-four percent of respondents have had visitors express that they do not like the toilet, while 40% have not made negative comments. Negative responses from visitors indicate a strong impact on the dignity of householders when their toilet is not found acceptable. Comments included expressing preference for the VIP toilet at home, requesting to use the neighbour's VIP instead of using the HS, and choosing to use the bushes rather than the HS toilet. Seventy-six of respondents reported that they are embarrassed by their toilet, 20% said they are not embarrassed.

3.3 Direct Sanitation Application (DSA) low flush design: Ifafa Grebe/Malengeni (Hibiscus Coast Municipality)

In this community, 1 865 DSA toilets were installed during 2002-2005. Twenty-six households were surveyed.

3.3.1 User reports of system functioning

Respondents reported the following components working or not working.

Table 3.5 Status of system components reported for DSA systems

Component	% reported working	% reported not working	% not reported
35 L reserve tank	76	24	0
Cistern	38	62	0
Flusher	31	62	7
Pedestal and pipes	46	54	0
Liquefier	42	58	0
Soakpit	58	18	24
Functioning	**% reported no**	**% reported yes**	**% not reported**
Soakpit reached capacity?	50	50	0
Experienced blockages?	32	68	0
Smells?	19	38	42

Some of the problems with systems reported by users related to improper installation at the beginning of the project by contractors. While 58% of respondents indicated that their liquefiers are not working, none of the systems had actually stopped functioning, indicating that excreta was still able to move from the pedestal to the pit, even if the system was not functioning optimally. Some of the liquefiers had never been sealed and buried properly by contractors during installation; in these cases evaporation would have been much greater than intended. Although the sludge was dry and crusted at the top in the liquefier, the system continued to function, indicating that wetter conditions must be maintained underneath. A third of reserve tanks were reported not working but no particular design flaw was apparent or reported. Because they are mounted on the outside of the house perhaps they are more vulnerable to the elements or to children tampering with them/placing objects in them or being vandalized. As 50% indicated that they use greywater for flushing, it is possible that as components in the greywater degrade over several days they cause build up in the tank which eventually results in blockages. If the 35 litre reserve tank is not functional, users can flush by filling the cistern directly or by pouring water into the pan with a bucket.

Figure 3.3 DSA liquefier tanks in Ifafa Grebe that were not properly sealed and covered with earth during installation

3.3.2 User behaviour

Respondents reported the following in terms of use of cleansing material, amount and type of water used for flushing, products used for cleaning and the use of the toilet for disposal of solid or liquid waste.

Table 3.6 Material reported entering DSA system (%)

Material reported entering DSA system						
Anal cleansing material	Toilet paper only	81%	Both toilet paper and newspaper	19%	Other	0%
Flush water	Tap water only	50%	Tap water and greywater	42%	Only greywater	8%
Amount per flush	2.5 litre or less	12%	5 litres	42%	10 litres or more	42%
Cleaning/unblocking products	Jeyes Fluid	31%	Household cleaners	19%	Washing powder	19%
Disposal of other household waste						
Greywater	Outside	73%	Toilet	8%	No response	19%
Rubbish directly into soakpit	Never	92%	No response	8%		

When asked about what might have caused blockages, half of the 8 responses pointed to a limitation in the design, including pipes being too small for the amount of excreta being flushed (3) and the flush being too small (1), while the other half pointed to inappropriate user behaviour: too much water being flushed (1), abuse by users (1), the previous owner having used something other than toilet paper for anal cleansing (1) and too much toilet paper having been flushed (1). Methods mentioned to clear blockages were: sticks (4), plastic gloves (2), Jeyes fluid (1), more water (1) and opening the system to unblock it (1).

While certainly many of the DSA pits were filling up and have needed to be emptied, it is difficult to determine the extent to which user behaviour such as the frequent use of water in excess of the design, presence of newspaper or chemicals which interfere with microbial action may compromise the optimal functioning of the design.

Of the 6 respondents who indicated that the household sometimes used newspaper for anal cleansing, one uses two litres to flush and reported no problems in the system after the flush and no blockages or breaks. The other three reported flushing with 5 litres, 10 litres and 20 litres: all reported blockages (one commenting: "I don't know why") and all reported the liquefier tank not working but no other problems in the system after the point of flushing, indicating that the liquefier tanks were, in fact, working.

Figure 3.4 Householder has used the lid from a reserve tank (left) to seal a liquefier tank which has not been properly sealed and covered (right).

3.3.3 User acceptance

Sixty-five percent of respondents reported that their feelings about the toilet have deteriorated over time, while 30% report that they still have the same level of satisfaction; 4% have never liked it. When asked how the design could be improved, 50% said they would like to convert to a waterborne system, 8% said they would like their toilet to be able to flush, 8% said they would prefer for the toilet to be outside, and 8% said they would like the toilet to be removed. Eighty percent reported negative reactions from friends and relatives, while 8% report no issues. In three cases relatives refuse to use the low flush toilet and two indicated that relatives don't like the low flush toilet because it is inside. Eighty-five said that they are embarrassed about their toilet; 12% said they are not.

IMPACT OF FAILED SYSTEM ON QUALITY OF LIFE

"The whole house smells."

"They laugh and it's insulting."

"They prefer the outside toilet. It's embarrassing."

"Sometimes they even prefer eating outside."

"They feel pity for us."

"There is no life with these toilets."

"They tease us. They say we live in a house with shit."

3.4 Social issues and lessons to be learnt

A number of social factors can be noted across the three studies which impact on the operational success and user experience of the systems. These include the choice of anal cleansing material, the multiple roles which a toilet might play in the life of a household, the view of respondents on having a toilet inside or outside the house and the role of the toilet in preventing contact with faeces.

3.4.1 Toilet paper/newspaper

Across the three case studies, the use of newspaper ranged from 8% to 19% with an average of 15%. Economic hardship – and unemployment, in particular – make it impossible for some households to buy toilet paper. Others budget for a pack each month and if it runs out they use newspaper for the rest of the month. As only twelve households reported using newspaper the sample was too small for very meaningful analysis, but among these households no consistent patterns could be seen in terms of blockages, full pits or having a toilet that smells. One respondent said that the toilet does block and they do think that their use of newspaper is the reason. Another said that they have problems due to the use of newspaper by former occupants. In general, systems which had to cope with newspaper did not appear to be having significantly more problems than those where users exclusively used toilet paper. However, due to the sensitivity of this issue, the use of newspaper may have been underreported. Since the reality is that there are families in South Africa which simply cannot afford toilet paper, the provision of basic sanitation must allow for this fact. If the use of newspaper truly causes these low flush systems to fail, perhaps these technologies are less appropriate as a free basic sanitation option than as an upgrade option for families interested in installing them at their own expense which can then be assumed to also have the means to buy toilet paper.

3.4.2 Role of the toilet in household disposal of waste

If a municipality has provided housing but no satisfactory option for disposal of greywater and solid waste generated by the household, householders may feel they have no option but to dispose of some waste in the toilet. If no reliable municipal rubbish collection is in place, householders will have to burn or bury solid waste or dump it in an empty lot. Not all waste burns; burning of plastics and other materials results in further contamination of the living environment. Discarding rubbish in trenches or empty lots can result in embarrassment and contamination if personal items are then strewn around the neighbourhood by animals or children. Householders with a VIP may find that it provides a convenient solution to some of these problems, even though it causes a new set of problems when it is time for the pit to be emptied. Householders with no VIP, such as in the three communities we visited for this study, may feel that flushing some items down the toilet is the only option in terms of safety, privacy or dignity, even if it has negative effects on the system. In town, householders can do away with unmentionables either through a reliable and anonymous rubbish collection system and at the same time their full flush toilets can make a number of items disappear as well. But for a family with no rubbish collection, no VIP and a flush toilet, where should pads or cloths for menstruation or incontinence, tampons, condoms or disposable nappies be disposed of? There are certainly countless other items (for example, hair extensions) which may never have been mentioned in user education and to the user may seem harmless enough to flush but can cause real problems inside a liquefier tank or vacuum tanker that is emptying a pit. While nearly all of the respondents in this study indicated that they never flush solid waste or put it directly into the soak pits, the research team has found some rubbish in pits while emptying HS low flush soak pits in France. During the survey, researchers observed a couple of examples of foreign matter in liquefier tanks in Ifafa Grebe.

The respondents in the three case studies reported the following behaviours in this regard:

Table 3.7 Disposal of greywater and solid waste

Community	Greywater disposal				Solid waste disposal				
	Outside	Toilet	Other	No answer	Rubbish collection only	Rubbish collection and burning	Burning	Other	No answer
France	55%	0%	13%	32%	29%	13%	29%	16%	13%
KwaNzimakwe	88%	12%	4%	0%	52%	4%	36%	8%	0%
Ifafa Grebe	81%	8%	0%	12%	73%	8%	12%	8%	0%

Sanitation providers need to be aware of the total waste disposal needs of a household and how the provision of a new system will impact this. In housing projects, the provision of a kitchen drain leading to a separate soak away for greywater would significantly aid families in the disposal of greywater and give the sanitation system a better of chance of functioning well if it is not overwhelmed with excess water and clogged with grease. Provision of a bathroom to allow for privacy during bathing and disposal of bathwater would also help to meet households' needs and prevent the overburdening of the sanitation system. And for an indoor toilet, provision of an indoor tap would facilitate improved hygiene in terms of hand washing.

3.4.3 Role of the toilet in the social context

While a toilet may have been installed at a household to improve sanitation, in the context of a large family sharing a small house the toilet may be used to meet other needs. Survey respondents indicated that the toilet is often used to store tools, clothes, towels, toiletries, cleaning equipment, toilet paper, basins for bathing, bottles, dishes, paint and petrol. While very few respondents from any of the communities indicated that they used the toilet for other activities – frequently citing the bad smell as the reason no one would stay in the toilet any longer than they had to – the few responses that were given included reading, bathing, grooming, praying, thinking, talking on the telephone and smoking.

Table 3.8 Other activities and purposes for which toilet is used by household

Community	Other uses of toilet			Other activities in toilet	
	Storage	**Other**	**None**	**Other activities**	**No other activities**
France	88%	0%	12%	16%	84%
KwaNzimakwe	52%	0%	48%	20%	80%
Ifafa Grebe	92%	0%	8%	16%	84%

3.4.4 Bringing sanitation inside?

While the political message from communities with basic sanitation across South Africa seems to be overwhelming that they want indoor flush toilets, the project team did encounter a small minority of respondents that were very unhappy about having their toilet inside. While the primary reason was the intolerable situation of living with a smelly indoor toilet, which has already been discussed, a few respondents said that it is embarrassing to have others know that you are going to the toilet and to possibly hear or smell what is going on in the toilet. This hints at the idea that bringing the toilet inside, for a family that has always had it outside, represents a shift in social behaviour. While it is safer and in some respects more convenient to have the toilet inside, for people living in a small house it affords less privacy. It is worth giving some thought to the proximity of the door of the toilet to the kitchen or living room in the design of the house, which may help to reduce discomfort. Another option might be to attach the loo to the house but with outside access, affording greater privacy to users still with easy access.

3.4.5 Primary role of toilet: preventing household contact with pathogens

While providing privacy and safety to users and addressing the broader issues of dignity and political aspirations are important aspects of sanitation provision, the primary purpose for the provision of toilets is to improve sanitation at the household by reducing contact with pathogens in faeces. To improve sanitation genuinely, the system must provide the household with the opportunity to avoid contact with pathogens and sustain this throughout the lifecycle of the system (construction, use, blockages and breaks, filling pits and emptying of pits).

The survey investigated two behaviours which present risk for exposure to pathogens which might be assumed to be eradicated through the provision of an indoor toilet: the use of a bucket as a toilet and open defecation.

Table 3.9 Reported use of bucket or outdoors for defecation

Community	Use of bucket	Open defecation
France	45% (5/11 responses)	30% (3/10 responses)
KwaNzimakwe	15% (3/20 responses)	35% (8/23 responses)
Ifafa Grebe	26% (6/23 responses)	26% (6/23 responses)
Average	**26% (14/54 responses)**	**30% (17/56 responses)**

While most respondents indicated that buckets were used for young children, one person said that when someone is sick with diarrhoea they use a bucket, while another said that her mother uses a bucket because her knees are weak. Generally buckets are emptied in the toilet, but one respondent indicated that it is emptied outside.

In terms of open defecation, two respondents reported defecating in the nearby forest instead of using the toilet. One said they sometimes dig a hole for the child to defecate into; another said they remove the child's faeces with a shovel. Another respondent said that they have let the child defecate outside but will stop this practice now because of plans to use that part of the garden.

The following issues may impact the success of a system in improving sanitation:

- Locating the toilet inside the house may significantly reduce the family's need for a "parallel" system such a bucket inside the house which may result in contact with faeces, but some households may continue to use buckets for children and members of the family who are ill or disabled.

- Constructing a house with an indoor toilet but no indoor kitchen or bathroom tap makes it inconvenient to wash hands – a critical step in preventing feacal-oral transmission of pathogens.

- Systems with liquefiers, tipping trays and strainers may require more risky "hands-on" involvement from householders to deal with blockages.

- Incorrect installation of pipes and tanks, where pipes or covers are open or exposed and can break or leak, can result in exposure to pathogens.

- Outdoor defecation is still happening sometimes – by children as well as adults.

- Unreliable rubbish collection means disposable nappies (and potentially newspaper) containing faeces could pose a risk if disposed of in a trench or empty lot where it could be torn open.

- Absence of a soak away for greywater means that contaminated water (e.g. water from soaking cloth nappies) may be dumped in the garden.

- If soak pits are buried and householders have no way to know that their soak pit is full until it begins to leak outside or back up into the bathroom, the purpose of the toilet is compromised. If a family finds itself in this situation their health is put at risk. A number have indicated in the survey they may have to continue to live with these conditions because they cannot afford to hire a vacuum tanker to empty their pit or a tanker may not be available.

- Careful precautions not taken during pit emptying to prevent spills or ensure that contaminated equipment does not come into contact with the household environment. Pit emptying could represent a point at which a household where sanitation has been improved for a number of years potentially becomes contaminated with pathogens not only from members of the household, their visitors and previous occupants but also from other pits that have been emptied with the same equipment.

- A significant number of respondents indicated that they empty their own pits or pay a neighbour or unemployed person to do it (paying between ZAR35 and ZAR200). Householders may not have the equipment and the understanding of transmission of pathogens necessary to properly protect themselves and the home from contamination. In the case of a professional service – which respondents indicated charge between ZAR100 to ZAR300, adequate protocols and provisions may not be in place to prevent contamination of households or to deal with spills.

3.5 Technical lessons to be drawn from three case studies

In many cases it is not possible to determine whether a problem has developed as a result of design / hardware issues, incorrect installation, normal wear and tear or user abuse. While in general respondents commented on issues they have had in the past as well as current issues, the survey probably does not accurately reflect what has been broken and fixed in the past. The fact that so many households are living with broken components raises the question of why they do not fix them. In the case of the HS model, replacement parts may not be available and it may be difficult to find a technician willing to rebuild the more unusual elements of the system. Still, in France many respondents reported efforts to fix their systems, sometimes doing the work themselves and sometimes hiring a technician. But while the designer of the DSA states that all parts are standard items widely available in hardware shops, virtually no attempts to repair or replace broken components was reported. While economic constraints may prohibit some users from being able to replace parts or hire technicians, it seems unlikely that this is the reason that virtually no repairs at all are reported by respondents in this community. In contrast, all of the respondents who had indicated having full pits (50%) had emptied them – with half of these hiring someone to empty the pits and half emptying themselves. So while economic power, initiative and ownership may all play a role in whether a household will maintain their system, it does appear that this may be more difficult or more expensive to do than with a standard flush toilet. A comparison with the status of component parts of a waterborne system in a community with a similar social profile might provide some insight into which issues persist when design variables are changed.

Table 3.10 Comparison of key aspects of three systems

	France (HS) 10-11 yrs old	**KwaNzimakwe (HS) 4-8 yrs old**	**Ifafa Glebe (DSA) 4-8 yrs old**
	Percentage reported working		
Cistern	28	48	38
Tipping tray	62	52	–
Liquefier	85	88	42
	Percentage reported YES		
Soakpit reached capacity?	81	50	50
Experienced blockages?	78	75	68
Smells?	61	54	33
	Percentage of users satisfied		
	20	20	30

(percentages based on total number of responses given for each question)

3.5.1 Reserve tank

The DSA reserve tank provides a practical and convenient way for users to fill their systems with water for flushing; giving access to the system from outside and providing 45 flushes before refilling is needed – in this sense most closely approximating a full flush toilet. While a third of reserve tanks were reported not working, no particular design flaw was apparent or reported. Problems might arise from the fact that being mounted on the outside of the house they are more vulnerable to damage by vandals or by elements and the high usage of greywater which may have grease or other residue which could clog the system. While this system component is outside of the scope of a pour flush design, the concept has much to offer.

3.5.2 One litre flush cistern

The most problematic aspect of the systems in all three communities appears to be the cisterns. In the case of the DSA toilets, some of the figures indicating cistern failure might in fact relate to the 24% of reserve tanks, which supply the cistern, which were not working. It is not apparent how user behaviour could have played a significant role in the failure of the cisterns, which suggests possible issues with the design, with quality of parts or with installation. While a toilet with a broken cistern can still function by being pour flushed, it is not designed as a pour flush and significantly more water may be required. Respondents indicate that when they pour flushed they typically poured 5 litres in, in some cases pouring as many as four bucketfuls to flush. A broken cistern therefore results in far more water entering the soak pit than it was designed to handle, perhaps resulting in faster filling rates or increased smell because of more anaerobic conditions. However, a number of users who reported that their cisterns do work also reported flushing with a bucket because the 1 litre mechanical flush was not enough. Others flushed the toilet two or three times for the contents to clear the pan. For users who have to fetch water from an outdoor tap, a toilet which uses 5-10 litres per flush is considerably more inconvenient than a toilet which uses one litre. In addition, while small children might be able to operate a flushing mechanism, fetching and pouring a 5 litre bucket is another story. In a household with many children, this could potentially result in repeated deposits of faeces and toilet paper before the toilet is flushed – potentially resulting in blockages. Some users report keeping a 20 litre bucket of water in the loo. This could potentially introduce a drowning hazard for young children (this is a consideration for pour flush systems as well).

While a functioning low flush toilet should not require householders to have to explain to their guests how to use the toilet, this is a factor with a pour flush design and can potentially be a source of embarrassment. What if the bucket with flushing water was left empty by the last guest, or there is not enough water left to finish the job? It is not desirable to have to explain to your guest how much water they should use for various bodily functions. These problems may be insignificant with a pour flush that successfully removes faeces and toilet paper from the pan with a single litre, but are exacerbated in the case of a low flush that has to be flushed with an entire bucket or more. For those moving from a homemade system or VIP to the apparent conveniences of an indoor flush toilet, this is one issue which does not arise with a dry system.

A pour flush design, in contrast to the low flush designs that have been studied, does not have the convenience and the similarity to a waterborne system of a cistern and flusher, but may prove more robust as it eliminates the problems caused by a malfunctioning water reserve tank, cistern or flusher.

3.5.3 Seals

The HS model uses a tipping tray to seal off the sight and smell of excreta from the pan. It is perhaps not surprising that respondents report that problems have developed with nearly half of the HS system's tipping trays over time, since it is a moving part vulnerable to breaks during cleaning, unblocking or perhaps flushing of newspaper or solid waste. Since the tipping tray and other HS components are not standard parts available in hardware shops, users have no way to replace a missing tray. Without the tipping tray, there is no seal to prevent unpleasant smells from escaping up through the pan and even from preventing worms from finding their way up the system into the pan. In the classic HS model in France, the liquefier, containing 25 litres of excreta, is located directly beneath the water seal, which is what the user sees looking into the pan if the tipping tray is missing, with unpleasant smells inevitably permeating the house. Some users have described that the tipping tray has actually gotten lodged in the solidified sludge below and no longer moves. In the DSA model, a water seal is created where the long radius pipe leading out of the pan levels off before it reaches the liquefier, which is located outside. Vent pipes also assist unpleasant gases to escape outside rather than back through the pan. This design is far more robust than having a tray that tips, but users still report unpleasant smells. Possibly if the system is not working smoothly the water creating the seal could be mixed with older excreta.

Neither of the seals provided in the HS or DSA designs seems to offer an advantage over a conventional water trap, which holds only the water from the most recent flush.

3.5.4 Liquefier tank and soak pit

The purpose of the liquefier tank in both HS and DSA designs is to help excreta begin to break down through the turbulence that occurs with each flush and through bacterial activity. The designers claim that by the time it reaches the relatively shallow soak pit it has reached a state where it can be completely digested by bacteria, resulting in no accumulation in the pit. However, there are no documented cases which indicate that zero sludge build up in an on-site sanitation system is possible. The design of the DSA is intended to create optimal aerobic conditions in the system so that it would not produce the unpleasant smells that pit toilets are notorious for, where sludge is decomposing deeper underground under anaerobic conditions (E. Bezuidenhout, pers. comm., 2010). Since the installation of the DSA units at Ifafa Grebe, the design has been modified further in order to promote greater oxygenation of excreta as it moves through the system. While the model found in Ifafa Grebe may not be as effective in this respect as the most recent version of the DSA, it does have the feature of letting excreta enter the liquefier from a high point in the liquefier tank which then displaces sludge into the entrance of a pipe near the bottom of the tank. This is intended to create conditions of constant motion, increasing oxygenation and preventing sludge from settling and solidifying on the bottom.

While again, it may not be so surprising to find problems with the liquefier tank, as an unconventional design element which has not been widely tested before and requires user behaviour which is not followed consistently in this community (e.g. no flushing of newspaper), the fact that all toilets in the survey were still usable indicates that liquefiers are not blocking completely, although a high number of users of both types of toilets reported liquefiers not working.

Soak pits were, however, filling up which suggests that the liquefiers were not achieving their purpose. In France, where systems had been in use for 10-12 years, 81% of responses indicated that pits have filled, while in KwaNzimakwe and Ifafa Grebe, where systems were 4-8 years old, responses indicated that 50% of pits were full – despite the different liquefier designs. While the presence of newspaper, solid waste (not reported but possibly still present in some cases), chemicals such as Jeyes Fluid, greasy dishwater or excessive amounts of greywater could impede the flow of sludge through the liquefier and total digestion in the pit, users did not report these materials entering the system frequently enough for it to account for the high percentage of full pits. The research team observed that while the DSA specifications for construction of the liquefier tank and soak away indicate that the lid of the liquefier tank must be sealed with silicon and the covers of both the liquefier and the soak away must be covered with at least 8 mm of soil, there were some which had never been covered at all and possibly were never sealed. In a number of cases in all three communities pits were found which were not properly covered. Open liquefier tanks and pits obviously would result in greater dehydration, possibly contributing to blocked liquefier tanks.

While it is unclear how many liquefiers had in fact blocked and to what extent this was due to incorrect installation or problematic user behaviour, they were not preventing, or significantly reducing, sludge build up in the pit. The theory and empirical observations around sludge accumulation in pit latrines and septic tanks indicates that sludge can be expected to accumulate at a rate of approximately 30 litres per user per year, and no amount of aeration will change this[2]. The liquefier tank does not seem to improve the functioning of a system and in fact appears to make it significantly more prone to problems in terms of the possibility of the exit pipe blocking from rags, newspaper, et cetera or from solidifying sludge. It can be appreciated that there will be difficulty with identifying problems and removing blockages from a component which, when properly installed, is sealed and buried without easy access. A straightforward pipe leading from the water trap to the soak pit would ensure more reliable functioning over time.

The purpose of having a shallower soak pit or French drain is to keep the sludge in the top layers of soil in order to facilitate aerobic digestion. Since this has not happened, the result is simply that households have a small soak pit. A number of respondents mentioned that the soak pit is too small; a few have extended it or built their own.

3.5.5 Smell

While the survey did not initially include a question about smell (it was assumed that a toilet with a water seal would not smell) 69% of respondents in the first case study (France) volunteered this information and the issue of the toilet smelling bad comes through as one of the greatest problems with all three studies. Certainly the unpleasantness of living in a small house with an indoor toilet that smells, and the enormous social cost which respondents report, could make this a most difficult problem to live with. What could be responsible for the bad smell? Certainly in the case of the HS model, a missing tipping tray would be a big factor as without it there is no water seal. With the DSA design, faeces will tend to back up in the pipe leading to the liquefier and this will lead to odours. Full soak pits could contribute, as well as poorly functioning liquefier tanks – whether located inside or outside of the house. If chemicals such as Jeyes Fluid or if solid waste is put into the system or if the toilet is used excessively for disposal of greywater, this could contribute to creating anaerobic conditions which produce unpleasant smells. However, no one of these factors correlates consistently with reports of bad smell. A number of respondents suggested that the soak pit be located further from the house to reduce smell, which might not always be possible. Possible design/behaviour interventions which might prevent the toilet becoming smelly could be:

- Use a water trap which does not rely on moving parts which can break/stick and which contains water only from the most recent flush, rather than the mixed contents of a long radius pipe leading to a liquefier.

- Develop a design without a liquefier, which is too susceptible to blockages or clogging up through dehydration if optimal conditions are not maintained.

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[2] See Volume 2 of the WRC report *TACKLING THE CHALLENGES OF FULL PIT LATRINES Volume 2: How fast do pit toilets fill up? A scientific understanding of sludge build up and accumulation in pit latrines,* WRC Report No. 1745/2/12, ISBN 978-1-4312-0292-8, which is published concurrently with this report.

- Stress during user education that if Jeyes Fluid, greasy water, newspaper, excessive greywater or solid waste is put into the system they could end up with a toilet that that smells.
- Select the location for the soak pit with consideration for the possibility that it might start to smell

3.6 Conclusion

The incidence of components not working in all three communities is high. Some problems have translated into inconvenience, some into health risks and others into extremely unpleasant living conditions. It is noteworthy that despite the many problems reported, not a single respondent reported a toilet that was completely unusable. Four reported that all components were still in working order: two HS systems in France and two DSA systems in Ifafa Grebe. In France, a household of four reported no problems with components and was satisfied with the toilet. However they have had to empty the soak pit. In the other case – a family of 13 – the toilet had to be flushed twice in order for excreta to clear the pan. Their soak pit had now filled for the second time. This family was very uncomfortable with having the toilet inside. With the DSA systems in Ifafa Grebe, two toilets were reported to have all components functioning and the soak pit had not yet filled. One reported needing 10 litres to flush (flushing with a bucket although the flusher works); they had experienced blockages and the liquefier pipe had a hole. They were satisfied with the system. Another reported blockages, needing to use 25 litres to flush (again, with a working flusher), and having problems with unpleasant smells during the night. The respondent expressed that they “hated” the system because it is inside. In KwaNzimakwe, no toilet in the survey was reported functioning without problems. While a handful reported no smell, respondents at these households indicated failure of almost all of the components.

It is clear that systems do not succeed or fail exclusively on the basis of design, although with new designs which have not been tested extensively problematic design elements may only reveal themselves over time. When systems rely on non-standard parts it also prevents users from replacing worn or broken parts. However, faulty installation and site conditions may create operational problems which do not derive from the design itself. In addition, user behaviour plays an enormous role in the success of a system. A sense of ownership, as well as economic status, will influence how well the system is cared for and whether necessary repairs are made. Disposal of rubbish, chemicals and greywater containing grease can interfere with the system or the functioning of the pit. If users cannot afford toilet paper and use newspaper or other materials for anal cleansing, these may also cause operational problems. Finally, the attitudes of users – whether shaped by cultural, political, or other factors – are often the decisive factor in whether they experience a system as successful or unsuccessful. If users perceive the toilet provided by the municipality as inferior, or find it uncomfortable to have an indoor toilet in a small house when they have had an outdoor toilet their entire lives, they may have strong negative feelings about the toilet even while it may be functioning successfully. For a system to be truly successful, therefore, it must not only be fit for purpose, but must also interface comfortably with cultural norms and meet users’ need for dignity and privacy, however symbolic or relative that may be.

Low volume flush technologies could potentially make important contributions towards providing basic sanitation in the South African context, but many behavioural and design challenges remain to be addressed.

4 DEVELOPING A PEDESTAL POUR FLUSH TECHNOLOGY

4.1 Designing a prototype

With consideration for the examples provided in the literature and lessons gained from user experience with related systems, the research team developed a prototype for a pour flush toilet designed to respond to the needs of households in the South African context. While there are arguments to be made in favour of a squat toilet (and many South African families of Asian descent do use squat toilets) this design is unfamiliar to most South Africans. It was felt that introducing a new way of defecating i.e. squatting would be inappropriate when the primary objective is to develop a sanitation option which satisfies the aspirations of users for something as close to a standard flush toilet as possible. The other key design challenge was that while Asian users use water for anal cleansing, to be useful in the South African context a pour flush system would need to be able to accommodate toilet paper, and even newspaper.

A pedestal was designed and a prototype manufactured from fibreglass. Externally, the pedestal looks similar to a standard flush pedestal. Internally, the pedestal does not have the bowl associated with full flush toilets, but is more funnel shaped. The front of the funnel slopes at 55° to 45°, while the back is near vertical. The funnel converges on a 70 mm diameter pipe which is angled 48° from the horizontal. This connects to a water trap made from 63 mm PVC pipe fittings. The key differences between this design and Sulabh's pedestal, apart from being designed for sitting rather than squatting, is the greater angle of the front slope of the pan (25 to 28° for the Asian pan and 55° to 45° for this pan), and the angle of the pipe exiting the pan (with the Asian units the pipe leaves vertically, whereas with this unit it leaves at approximately 45°). The changes in these slopes are driven partly by the change from a squat pan to a seat, and partly by the desire to facilitate the clearing of blockages from the S bend.

Figure 4.1 The pour flush pedestal prototype. The pan funnels steeply to a 70 mm diameter outlet, which is angled at 45° to the horizontal.

The depth of the water seal provided is 25 mm. With the Asian designs the recommendation is at least 20 mm, so in this respect the two designs are similar.

Figure 4.2 The water seal is made up using three standard 65 mm diameter PVC pipe fittings – a reducer, a long radius 90° bend, and a 45° bend

4.2 Testing the prototype

The flushing performance of the pour flush prototype was tested using the *Maximum Performance (MaP) Protocol* (2005) developed by Veritec Consulting Inc. and Koeller and Co for the USA and Canada. The protocol specifies that a toilet must completely evacuate 250 g of a simulated faecal matter plus toilet paper in a single 6 ℓ flush, without plugging or clogging, on 4 of 5 attempts in order to pass. [3]

Figure 4.3 The test samples made up according to the method prescribed by the MaP test protocol. Each sample contains 50 grams of soy paste, and is contained in a latex sheath.

[3]This benchmark for faecal load is based on the British medical study *Variability of Colonic Function in Healthy Subjects* which identifies 250 g as the average maximum colonic load of an adult male. The US EPA uses 350 g – representing a 99.5 percentile threshold – as its standard.

The pedestal was placed on a level surface and the samples were dropped into the pan followed by 4 wads of 5 squares of single ply toilet paper. Water was then poured into the toilet in volumes 0,6 ℓ to 1,3 ℓ per flush. During the first trials water was poured from various heights, but it was soon found that the correct action for flushing the toilet required more of a "dumping" action than a pouring action, and for this action dumping from just above the seat level worked well.

Figure 4.4 The test set-up. For each flush test up to six 50 g replica faecal samples were placed in the pan with a prescribed amount of toilet paper (20 squares of single ply).

Thirty-one trials were completed. Nineteen trials were done using 250 g of material, and twelve trials done with 300 g of material. For the 300 g test, all trials using 1 ℓ or more of water were successful in flushing all of the samples through the water seal, whereas with the 0.8 and 0.9 ℓ flushes not all the test samples were successfully removed.

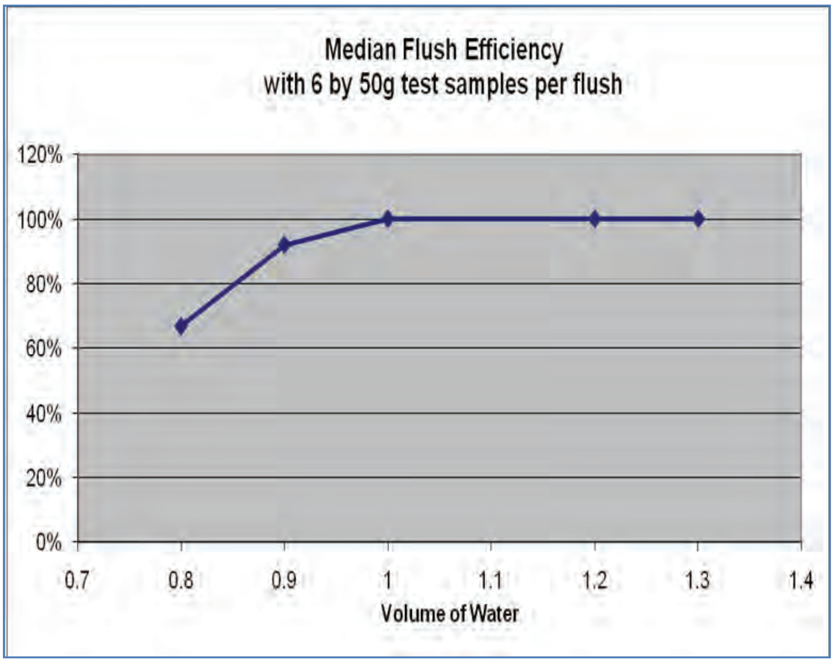

Figure 4.5 Results for the 6 by 50 g flush tests. A 1.0 litre flush was found to be sufficient to clear the pan.

Flushing of newspaper was also tested. Twenty trials were conducted using six 50 g test samples with varying amounts of newspaper and water, which are summarised in Table 4.1. Two methods were tested. For the first, a single litre was poured into the pan and given 30 seconds to soak into the newspaper, reducing the volume, after which an additional litre was poured into the pan. For the second, two litres was poured directly into the pan. It was found that pouring 2 litres in a single flush was just as effective as two single litre flushes. While all test samples and newspapers were not cleared with the first 2 ℓ flush, test samples with 4 or 6 pieces of newspaper (which were ¼ of a sheet) could be cleared with additional water. When flushing 8 sheets of newspaper was tested, however, some blockages occurred which had to be cleared manually. It is recommended, therefore, that users do not try to flush a large amount of newspaper at one time.

Table 4.1 Flushing of newspaper tested

No. of trials	No. of wads of newspaper (¼ sheet each)	Flushing method	Result
5	4	1 ℓ, wait 30 seconds, followed by 1 ℓ	Cleared 100% on first attempt 2 trials (40%) remainder cleared with additional water.
5	4	2 ℓ	Cleared 100% on first attempt for 3 trials; remainder cleared with additional water.
5	6	2 ℓ	Cleared 100% on first attempt for 2 trials (40%); remainder cleared with additional water.
5	8	2 ℓ	Cleared 0% on first attempt; All cleared first 2 ℓ: 0%; 60% cleared with additional water, 40% would not clear with additional water.

4.3 Testing the design in homes

Two households were selected for the initial field tests. Both homes belonged to family members of colleagues of the project team who had previously asked for assistance in improving their household sanitation. The existing working relationships facilitated communication, logistics during building and transfer of knowledge.

Both households had piped water and a VIP toilet with a wooden seat and corrugated iron structure which had been built by the municipality and was approximately 20 years old. In the past, the families had moved these toilets when the pits had become full, but this was becoming more difficult as their plots were small.

4.3.1 First test toilet

At Household 1 a VIP toilet, which was still in fair condition, was used by the family of four adults. The homeowner elected to have an outdoor structure built for the pour flush toilet rather than installing it indoors. A location was identified behind the house near the back door for the pour flush. Because the house is situated on a deep cut where the permeability of the soil is low, it was necessary to identify a site in front of the house (down slope) for the construction of the twin soak pits. This required a 16 metre long sewer with a manhole at the 90° bend around the corner of the house, and a splitter box to enable the flow to be switched between the two soak pits. Partly due to the topography of the site (and partly due to the inexperience of the construction crew) this sewer was laid at flat grades (1% for the first section, 2% for the second section, and 3% for the final section).[4]

Figure 4.6 (left) Structure built behind house; first manhole in left corner

Figure 4.7 (below) Existing VIP (left) and new pour flush in structure (right) at Household 1

[4]The typical guidelines for sewer slopes in these situations are between 1:15 and 1:50. Slopes steeper than 1:50 may not always be achievable if the distance between the toilet and soak pit is long, because for maximum absorption the entry point into the soak pit must be as close to the surface as possible.

Figure 4.8 First and second junction boxes of sewer at Household 1. The second is a splitter box, where the flow is routed to either one of two leach pits using a section of PVC pipe as the switch.

The pits were lined with M200 concrete blocks lain sideways to maximize leaching and to maximize the sludge/soil interface (which is believed to accelerate sludge breakdown). The internal dimensions of the pits were 1.0 metre by 0.8 metres by 1.4 m deep. The useful depth depends on the level of the pipe coming in.

Figure 4.9 Interior of a soak pit (left). Each pit is covered by two 1.2 m by 1.4 m precast concrete slabs (right)

Figure 4.10 The completed soak pits (either side of the tree) are covered with topsoil. (At a later date inspection ports were added to aid with the checking of sludge depth)

4.3.2 Second test toilet

At Household 2, an indoor flush toilet connected to a septic tank served the main house while tenants living in an outbuilding still used the VIP toilet, which was in poor condition. The family had moved the VIP toilet twice since it was built because the pit was full.

Figure 4.11 Existing VIP toilet at Household 2.

The family identified a room in the outbuilding which could house the test toilet. The pour flush toilet was to be used primarily by the four adult tenants, and it was connected to the existing septic tank.

Figure 4.12
Pour flush toilet installed in an out building at Household 2

4.3.3 Commissioning

On 1 September 2010, after the new sewers had been flushed, they were tested. As with the trial for the prototype, 6 samples of "excreta" and 4 wads of 5 squares of single ply toilet paper were flushed with 1 litre of water. At Household 2 (with a short sewer leading to a septic tank), the samples reached the first box with the first flush and the second box with the second flush. At Household 1 (with a 15 m sewer), the samples did not appear at the first box (six metres from the toilet) after the first 1.5 ℓ flush. With an additional flush, some of the samples appeared at the first box. By the time the water had reached the box it had slowed significantly so that it no longer had the force to move the samples further. Two 5 ℓ buckets of water were then poured into the toilet in order to flush all of the samples as far as the second box (a further 7 metres distance). Householders at both homes were instructed to experiment with flushing with 1-2 ℓ to see what they found to be adequate.

Each household was provided with a toilet brush, a rod for clearing blockages (a radiator brush inserted into a piece of hosepipe sealed at one end with duct tape), a packet of 24 rolls of single ply toilet paper, a 10 ℓ bucket, a 1.5 ℓ jug and a spray bottle. A toilet roll holder had been installed in each structure.

4.3.4 Monitoring

During the first month of operation, each household was provided with a weekly monitoring sheet on which to document daily the number of times the toilet was flushed, the number of toilet rolls used, the number of times the toilet was cleaned and problems or ideas related to the toilet. Weekly monitoring visits were made during the first month during which manholes were inspected and the sewer at Household 1 was tested once again with toilet paper and a 1.5 ℓ flush. Occasionally, faeces was found in the channels, appearing to move in stages through the sewers with each flush without causing blockages. Despite the fact that water does not sit in the pour flush pan as it does in a standard flush toilet, the pans appeared minimally soiled even with cleaning reported by users less than once a week.

After the initial month of operation, monitoring visits were made monthly for the remaining first six months of use after which monitoring was conducted less frequently through phone calls, feedback from family members (colleagues of the project team) and occasional visits. To date, no problems have occurred with either toilet after 22 months of use with the exception of a blockage (described in Section 4.4.2) at Household 1 caused by a plastic packet which had been flushed down the toilet by a child.

Acceptance expressed prior to the commissioning of the toilets and during the four monitoring visits since was high. Household 1, with 3 adults – 2 at work during week – reported using 1.5 to 2 litres per flush. Their reported water consumption was 540 litres for the month. Household 2, with 2 working adults during week, 4 adults on weekend, used a 1.5 litre flush and reported using 210 litres of water over the month.

4.4 Piloting the technology

After the two test toilets had been in operation for four months with no problems, construction began on 18 additional units which were installed over the course of 2011.

4.4.1 Selection of households

As neighbours and friends of both families with test toilets had expressed interest in having a pour flush toilet installed as well as a willingness to pay something for the toilet – despite the fact that waterborne sewerage was expected to be provided to the area within the next few years – a demonstration session was held on 13 November, 2010 and site visits were made to those who were interested. This provided an opportunity to explore the possibilities for pour flush technology as a demand-driven option for householders who would like to upgrade their sanitation system. Owners were quoted R2000 (with costs estimated at R2750) for construction of soak pit and installation of a pedestal and R4000 (with costs estimated at R6000) if a structure had to be built as well. Costs were discounted because the technology is still being piloted and owners would participate in the research in terms of cooperating with monthly monitoring. Ultimately only one resident (Household 3) decided to install a pour flush toilet. He paid a deposit of R1000 before construction of the soak pit and installation of the pour flush pedestal and another R1000 upon completion.

Selection of households for the pilot study was made as follows:

- **3 units built in Azalea for households with VIPs** (uMsunduzi Local Municipality). Colleagues of the research team and a neighbour participated, as described above.(Commissioned in September 2010 and January 2011).

- **8 units built in France and adjacent communities** (uMsunduzi Local Municipality). Initially, 5 households were identified which had been found to have failed HS systems during the case study conducted in the area as part of this project (described in Chapter 2). While conversions at these homes were underway, the construction manager identified other households with homebuilt sanitation while working in the area. Consent was obtained from the local councillor. (Commissioned in December 2010 and January 2011).

- **4 units built in rural Mafunze** (uMsunduzi Local Municipality). Sites were selected by the local councillor. Basic service provision in the area was VIPs (Commissioned in March 2011).

- **5 units were constructed in Siyathuthuka**, in the Richmond area (uMgungundlovu District Municipality). This was an area where Hungerford-Schroeder low flush systems had been installed inside one room RDP homes in 2006-2007. The District Municipality expressed interest in participating in the pilot project in November 2010, but due to political issues around sanitation delivery in the municipality the project had to be discussed at a number of meetings over subsequent months. In September 2011 the municipality indicated that the Siyathuthuka community in Richmond had been selected. Following a community meeting, the local councillor identified five households for conversion, and construction began at the end of October. (Commissioned in November 2011).

Figure 4.13 Uncovered or poorly covered soak pits in Siyathuthuka

4.4.2 Construction and operation of pilot units

The construction of pour flush units and their operational history is detailed below according to whether the household members were previously pit users (municipal VIP or homebuilt latrine) or low flush system users (HS toilets, conversions to DSA or full flush). Only one problem was encountered with the operation of any of the 20 systems: a blockage was caused when a child flushed a plastic packet down the toilet at Household 1 (detailed below).

All toilets were equipped with toilet paper dispensers and a hand washing facility was mounted on the wall of the outdoor structures. Construction was inspected after completion by the research team. Each household was provided with a pack of 10 rolls of toilet paper, a 10 litre bucket for storing flushing water in the toilet, and a 2 litre jug for pouring water into the toilet. The care of the toilet was discussed with a householder. An educational poster was mounted on the back of the loo door explaining how to use and care for the toilet (See Appendix B)

Figure 4.14 Outdoor structure with pour flush pedestal. A handwashing facility is mounted on the right hand side of the structure. The bucket and jug for flushing are stored in the loo and a poster explaining how to use and care for the system is mounted on the inside of the door

Table 4.2 provides a summary of the conversions that were done for each household in the pilot study and operation since construction.

Table 4.2 Summary of conversion, construction and operation data for pour flush pilot units

Household number	Area	Previous sanitation	Pour flush installation	Construction			Operation
				Structure	Soak pit	Sewer	
1	Azalea	VIP	Outdoor	Y	Y	15 m	1 Blockage from packet, see below
2	Azalea	VIP	Indoor	N	N	Y	No problems
3	Azalea	VIP	Outdoor	N	Y	Y	No problems
4	France	Homebuilt	Outdoor	Y	Y	Y	No problems
5	France	Homebuilt	Outdoor	Y	Y	Y	No problems
6	Mafunze	VIP	Indoor	N	Y	25 m	No problems
7	Mafunze	VIP	Outdoor	N	Y	Y	No problems
8	Mafunze	VIP	Indoor	N	Y	Y	No problems
9	Mafunze	None	Outdoor	Y	Y	Y	No problems
10	Siyathuthuka	Homebuilt	Outdoor	Y	Y	Y	No problems
11	France	Homebuilt	Outdoor	Y	Y	Y	No problems
12	France	HS	Indoor	N	N	Y	No problems
13	France	HS	Indoor	N	N	Y	No problems
14	France	HS	Indoor	N	Y	Y	No problems
15	France	HS	Indoor	N	Y	Y	No problems
16	France	HS	Indoor	N	Y	Y	No problems
17	Siyathuthuka	HS	Indoor	N	Y	Y	No problems
18	Siyathuthuka	HS	Indoor	N	Y	Y	No problems
19	Siyathuthuka	HS	Indoor	N	Y	Y	No problems
20	Siyathuthuka	HS	Indoor	N	Y	Y	No problems
TOTALS	**A:3, F:8 M:4, S:5**	**VIP:6, HS:9 Hb:4**	**Outdoor: 8 Indoor:12**	**6**	**16**	**20**	**Excellent**

Ten pit latrines were converted to pour flush systems, including 6 VIPs and 4 homebuilt latrines. Nine Hungerford Schroeder low flush units were converted. One toilet was built for a church under construction where there was no previous sanitation. Twelve pour flush toilets were installed inside homes and 8 were installed in outdoor structures. Six structures were built to house pour flush toilets and 16 soak pits were constructed. Sewers were constructed for all toilets to twin soak pits.

A description of the sanitation history, construction and operation for household are provided below.

CONVERSIONS FROM PIT LATRINES TO POUR FLUSH SYSTEMS

Household: 1	Area: Azalea	Commissioned: 1 September 2010

Sanitation history: Twenty year old municipal VIP; seeking upgrade to flush system without high water usage.

Construction: Detailed above in Section 2.3

Operation: At 13 months of operation, the owner reported that his toilet was blocked. Water, toilet paper and faeces was found backed up in the splitter box preceding the two pits. The pit was opened and it was found that a plastic bag was blocking the pipe between the splitter box and the pit.

Figure 4.15 Blocked sewer leading to soak pit (left). The cause was a plastic packet which can be seen hanging from the pipe exiting into the soak pit (right).

Figure 4.16 Sewer cleared after plastic packet is removed

The packet was removed from the pipe and the blockage cleared, restoring the system to normal functioning. One of the children admitted to having flushed the packet down the toilet because he had been told not to flush newspaper and he was curious to see if a packet could be flushed successfully. The home owner was irate about the incident

Household: 2	Area: Azalea	Commissioned: 1 September 2010

Sanitation history: Twenty year old municipal VIP; seeking upgrade to flush system without high water usage.

Construction: Detailed above in Section 3.3

Operation: No problems.

Household: 3	**Area: Azalea**	**Commissioned: 18 January 2011**

Sanitation history: Twenty year old municipal VIP with full pit.

Construction: A soak pit was constructed and a pour flush toilet was installed in an outdoor structure built by the home owner.

Operation: No problems experienced except that screws holding the toilet seat became loose and were tightened.

Figure 4.17 Household 3: Pour flush toilet installed in outdoor structure.

Household: 4	Area: France	Commissioned: 18 January 2011

Sanitation history: Home built latrine. Afraid of floor breaking and someone falling into the pit.

Construction: A top structure and soak pit were built and a pour flush toilet installed.

Operation: No problems.

Figure 4.18 Household 4: A structure was built for Household 4 to house the pourflush toilet.

Household: 5	Area: France	Commissioned: 18 January 2011

Sanitation history: Home built latrine. The house had been built with an indoor HS system which the family did not find acceptable. The family used a home built latrine they had constructed themselves. They did not want another indoor toilet.

Construction: A top structure and soak pit were built and a pour flush toilet installed.

Operation: No problems. The pit tended to collect rain water.

Figure 4.19 Household 5: Existing home built latine (left) and pour flush under construction (right)

Household: 6	**Area: Mafunze**	**Commissioned: 9 March 2011**

Sanitation history: Municipal VIP. Satisfied with VIP, but chose pour flush because interested in having an indoor toilet and willing to participate in study.

Construction: A top structure and soak pit were built and a pour flush toilet installed with a 25 m sewer to the soak pit.

Operation: No problems. A member of the household was injured in an accident soon after the pour flush had been installed, and the family expressed that while they had been very satisfied with their VIP (having solved the problems experienced with home built latrines) they had appreciated the convenience of having an indoor toilet enormously during her recovery while her mobility was limited. Users flushed with 2 litres due to the long sewer.

Figure 4.20 Household 6: Existing municipal VIP (left) and pour flush pit under construction (right)

Household: 7	Area: Mafunze	Commissioned: 9 March 2011

Sanitation history: Two municipal VIPs and an indoor full flush toilet with a septic tank system.

Construction: The construction team filled in the existing VIP pit, then removed the VIP pedestal and replaced it with a pour flush pedestal, cementing it in place. A soak pit was constructed behind the VIP pit with the pipe for the pour flush passing through the VIP pit to the pour flush pit.

Operation: No operational problems were reported. Water and toilet paper were not found in the loo on visits. On one visit the toilet had not been flushed or cleaned after someone had defecated. The owner kept the toilet locked with a padlock. After 4 months of operation he lost the key and on subsequent monitoring visits had still not cut the lock off. This participant was selected due to his status in the community and may have been a poor choice.

Figure 4.21 Household 7: Previous VIP toilet (left) converted to pourflush (right).

Household: 8	Area: Mafunze	Commissioned: 9 March 2011

Sanitation history: One municipal VIP and one home built pit latrine. No problems with existing sanitation.

Construction: The construction team installed a pour flush toilet in the corner of a large garage attached to the family's shop. The construction team did not build walls around the toilet as the owner is planning to build a larger bathroom around it. The team constructed a soak pit on the other side of the driveway.

Operation: The toilet is in a garage where animals are also kept, and the toilet and general area were found quite dirty on visits, with toilet paper strewn on the floor. No problems were reported by the owner, but on 14.9.11 the research team found the toilet badly soiled with a broken toilet brush stuck in it. An employee said the brush had broken in the toilet that morning and that he would remove it later.

Figure 4.22 Household 8: Two existing VIPs and digging of soakpit (left). VIP installed in garage where animals are also kept; owner intends to enclose part of the garage as a bathroom (right).

Household: 9	Area: Mafunze	Commissioned: Not yet commissioned

Sanitation history: None: built for church building that is still under construction.

Construction: The project team constructed a structure and soak pit and installed a pour flush pedestal.

Operation: As the church was still under construction, the toilet had not yet been formally commissioned for use. Educational materials will be provided when the church is ready to introduce users to the pour flush technology. After construction the bottom of the pit filled with water before the system was commissioned.

Figure 4.23 Top structure (left) built for church with soak pit collecting some water (right)

Household: 10	**Area**: Siyathuthuka	**Commissioned:** 6 December 2011

Sanitation history: None provided by municipality; homebuilt latrine**.**

Construction: The construction team built an outdoor structure with a pour flush system and soak pit.

Operation: No problems. One householder said that his mother is quite large and prefers to use the old home built latrine because she finds the pour flush structure too small.

Figure 4.24 Household 10: Home built structure for a latrine at a home which was overlooked when HS systems were originally installed (left); new pour flush system (right)

Household: 11	**Area: France**	**Commissioned: 22 December 2011**

Sanitation history: The family had removed the original HS system from the house and built their own latrine, using the HS pedestal over the pit.

Construction details: An outdoor structure and soak pit were constructed and a pour flush pedestal installed.

Operation: No problems.

Figure 4.25 Household 11: Homebuilt latrine with HS pedestal (right). Pour flush system under construction (left).

CONVERSION FROM LOW FLUSH SYSTEMS TO POUR FLUSH SYSTEM

Household: 12 **Area: France** **Commissioned: 17 December 2010**

Sanitation history: Indoor HS low flush system. Existing soak pit full.

Construction: The construction team replaced the existing indoor HS system with a pour flush system. The existing soak pit was full. The team emptied this for continued use.

Operation: Six visits were made to the site; no one was home on two of these visits. The householders reported no problems with the toilet but concerns about not being able to afford toilet paper and that newspaper might block the system. The research team encouraged her to try to use newspaper using the method of flushing small amounts of newspaper at a time and told her to call the research team immediately if she experienced any problems. The contents of the pit were measured on 1.5.12 (approximately 1 year in use). Details are provided in Section 4.5.11.

Figure 4.26 Household 12: Pour flush toilet installed.

Household: 13 **Area: France** **Commissioned: 17 December 2010**

Sanitation history: Indoor HS low flush system. Cistern and tipping tray broken; soak pit full.

Construction: The construction team replaced the existing indoor HS system. The existing soak pit was full. The team emptied this for continued use.

Operation: Eight visits were made to the site. In May, the seat and lid were found to have come off the toilet. It was found that some of the screws had not been tightened properly and the problem was resolved. An unpleasant smell was noted on one visit even though the toilet appeared very clean. The homeowner was asked to monitor water and toilet paper usage for a month; however, data that was collected appeared unreliable.

Figure 4.27 Household 13: New pour flush toilet

Household: 14 **Area: France** **Commissioned: 14 January 2011**

Sanitation history: Indoor HS low flush system; soak pit had been built in front of the door to the house.

Construction: The problematic HS system was removed and a pour flush toilet was installed. The previous soak pit had been constructed directly in front of the front door of the house and so a new soak pit was built in a more suitable location and the old pit was backfilled. During the first attempt to dig a soak pit the construction team hit an underground spring and the pit filled with water. This pit was filled again and another pit was dug in a different location.

Figure 4.28 Household 14: Householder stood on lid during first week of use and broke it.

Operation: The site was visited six times; no one was found at the house three of these visits. During the first week of use the householder stood on the toilet lid while painting the bathroom and broke the lid in half. She then placed the old HS lid over the broken lid of the pour flush pedestal. She said that she preferred the old HS seat. She reported that the toilet had an unpleasant smell. She used a 5 litre bucket to flush because she believed that this much water was needed to flush the toilet because of the long sewer even though the toilet had never blocked. She reported that she did not like having the toilet inside. She mentioned that children sometimes forgot to flush. The contents of the pit were measured on 1.5.12 (approximately 1 year in use). Details are provided in 4.5.11.

Household: 15	Area: France	Commissioned: 14 January 2011

Sanitation history: Indoor HS low flush system.

Construction: The family was in the process of extending the house and chose a location for the pour flush toilet which was in the new section that was still being built. A new soak pit was constructed with some difficulty because of the many large rocks which had to be removed.

Operation: Seven monitoring visits were conducted. No problems were found; the family used 2 litres to flush as the sewer is quite long. The contents of the pit were measured on 1.5.12 (approximately 1 year in use). Details are provided in Section 4.5.11.

Figure 4.29 Household 15: Large rocks removed for construction of soak pit (left); soak pit installed in new extension of the house (right)

Household: 16	Area: France	Commissioned: 14 January 2011

Sanitation history: Indoor HS low flush system with home built soak pit.

Construction: The construction team replaced the indoor HS system with a pour flush toilet and constructed a new soak pit.

Operation: Six monitoring visits were made; no one was home at one of these. The homeowner reported that that she found that the toilet had an unpleasant smell when she flushed with 2 litres but not with 1 litre. She said that 1 litre is adequate to flush the toilet. The householder was asked to monitor water and toilet paper usage for one month, however the data that was collected appeared unreliable. The contents of the pit were measured on 1.5.12 (approximately 1 year in use). (Details are provided in Section 4.5.11).

Figure 4.30 Household 16: Old HS pedestal removed (left); new pour flush system during installation (right)

Household: 17	**Area**: Siyathuthuka	**Commissioned: 6 December 2011**

Sanitation history: Indoor HS low flush system with home built soak pit; broken tipping tray.

Construction: The construction team replaced the existing indoor HS system. The home built soak pit was filled with earth and a sewer was laid through it to a new soak pit.

Operation: No problems noted or reported.

Figure 4.31 Household 17: HS system with missing tipping tray which had not been flushed because the water supply was cut off (right). Rodding eye (white) indicates sewer laid through old pit to new pit (left).

Household: 18 **Area**: Siyathuthuka **Commissioned: 6 December 2011**

Sanitation history: Indoor HS low flush toilet system with home built soak pit had been converted to full flush system.

Construction: The construction team replaced the full flush system which was unable to function properly with the available water supply. The cistern had to be filled manually for each flush. The homebuilt soak pit was filled with earth and an 18 m sewer was laid through the two previous soak pits to a new soak pit.

Operation: No problems noted or reported.

Figure 4.32 Household 18: Full flush pedestal (left) replaced with pour flush system (right)

Household: 19 **Area**: Siyathuthuka **Commissioned:** 6 December 2011

Sanitation history: Indoor HS low flush toilet with broken tipping tray and full pit. The toilet could only be flushed by rodding contents through the pedestal.

Construction: PID replaced the existing indoor HS system. The homebuilt soak pit was filled with earth and a sewer was laid through it to a new soak pit.

Operation: No problems noted or reported.

Figure 4.33 Household 19: New pour flush pedestal installed in the house (left) and soak pit constructed and covered with earth behind the house (right).

Household: 20 Area**: Siyathuthuka** Commissioned: **6 December 2011**

Sanitation history: Indoor HS low flush toilet converted to DSA which did not work well: the cistern had to be filled manually for each flush.

Construction: The DSA system was replaced with a pour flush system. The home built pit was filled with earth and a sewer laid through it to a new soak pit.

Operation: No problems noted or reported.

Figure 4.34 Household 20: Family had converted the original HS system to a DSA system which proved problematic.

4.5 Evaluation

A survey investigating system functioning, user behaviour and user perceptions was conducted for 19 of the households in the pilot study (the church provided with a pour flush toilet was not included in the survey as the church itself is still under construction). The last unit was constructed at the end of the project and so previous behaviour/experience was captured but not experience/behaviour subsequent to installation of the pour flush for this household). Key observations are summarised here followed by detailed information captured by the survey. The survey questionnaire (Appendix C) and responses (Appendix D) are attached. Evaluation of system condition over time, water usage and pit filling rates follow after the survey data.

Table 4.3 Key observations with regard to use of pour flush

Previous sanitation:	Pit latrine	HS
User behaviour (pour flush)		
Newspaper used for anal cleansing	33%	0%
Use of bucket concurrent with toilet	20%	11%
System functioning		
Problems with flushing	0%	0%
Smell reported	0%	22%
User attitudes		
Householder expressed some criticism of pour flush	0%	56%
Visitors expressed some criticism of pour flush	0%	33%
Preference for locating toilet outside	60%	56%

Respondents indicated that it is not possible to always buy toilet paper, but while a third of former pit latrine users had begun to use newspaper at least some of the time – without experiencing blockages – former HS users had not, with some expressing difficulty with buying toilet paper but fear that using newspaper would cause blockages. Buckets continued to be used for urine during the night by some households even if the toilet is located indoors. None of the respondents reported difficulties with flushing. The negative experience of HS with toilets causing an unpleasant smell to permeate the house has been expressed as a key concern and was the reason given for a majority (56%) of former HS users preferring an outside toilet. The criticism most often expressed by visitors in communities with HS systems was that the pour flush toilets had been installed inside, as they were concerned that the system would begin to have an unpleasant smell over time. While no former pit latrine users expressed criticisms of their new pour flush systems, 56% of former HS respondents expressed that that while they were satisfied with the pour flush system there was an aspect they wished was different: two found that it smelled, one wished it had a mechanised flush, one did not like to see excreta in the pan, one found the outdoor structure too small, one preferred the HS toilet seat and one wished it was not necessary to flush after urinating.

4.5.1 Household data

Household size ranged from 1 to 10, with a mean size of 5. Thirteen of the 19 respondents were women.

4.5.2 Sanitation and housing history

RDP houses with HS systems

The 12 houses in the France (7) and Siyathuthuka (5) areas were built as one room RDP houses; 3 families have built on additional rooms. HS low flush systems were originally installed inside these small dwellings during construction, although at one home in Siyathuthuka no sanitation system was ever installed. In Siyathuthuka the houses were built in 2006-2007 and the loos are relatively spacious, with a bathing area with a drain and tap and adequate room for storage. The houses in the France area were built in 1999-2001; these have smaller loos accommodating only the pedestal and with no facility for bathing. The 5 households in Richmond reported that soakpits were never built and they constructed these themselves. These were often covered inadequately with scrap material or with nothing at all. Four of these twelve households have removed their HS system from their home; two built their own latrines outside (one using the HS pedestal over a pit) and the other two replaced the HS pedestal with a DSA or full flush pedestal. The water supply and pits were inadequate for toilets using a higher volume of water.

Problems with the HS systems ranged from unpleasant smell (8), blockages (5), full pit (5), a broken cistern (2), insects entering the house through the cistern, difficulty cleaning the tipping tray and a tipping tray having broken off (3). One respondent reported that three years after they had moved into the house the toilet stopped working and they have had to use the neighbour's since then.

Six of the households using HS systems reported that their pits had filled; two dug disposal holes and emptied their pits with buckets. This was unhygienic and they found it was impossible to empty the pit fully. Another household dug a new pit and extended the sewer.

Owner-built homes with pit latrines

The 3 houses in the peri-urban area of Azalea are larger (4 or more rooms) cement block houses built by owners which were provided with VIPs (round corrugated iron structures) built by the municipality, some as long as 20 years ago. In rural Mafunze, two of the homes consist of larger compounds with both cement block and wattle and daub structures, while the third family lives above their shop. These households were provided with cement block VIPs in 2007 and 2010. One home in France is a home built wattle and daub structure which had a home built latrine; this family has no water supply on site and relies on a neighbour's tap.

Problems reported with the VIPs were that they were deteriorating with age, were difficult to empty, that it was unpleasant to have to go outside to use the toilet in inclement weather and that it was preferable to flush away excreta. Problems reported with home built latrines were that the structures leaked in rainy weather, wetting the seat and toilet paper and filling the pit with water and that the floor boards were breaking and householders were afraid that the floor might collapse and someone might fall into the pit. Four pit latrines have become full; two families dug new pits and moved their structures.

4.5.3 Acceptance and perceptions of pour flush

Reasons given by households with an HS system for agreeing to have a pour flush installed included:

- Told it would not smell
- Flushes well
- Easy to clean
- Needed an improvement from an unsatisfactory/failed system (one indicated that visitors no longer come to their house)

Reasons given by households with pit latrines:

- An indoor toilet would provide the convenience of not having to go outside to the toilet at night, in inclement weather, or when you are sick
- Reduce smell/flies
- Although residents in Azalea will soon be offered waterborne sanitation, 3 households selected pour flush (one at his own expense) because the one litre flush will save on water costs over full flush systems
- Safer than home built structure with deteriorating floor boards
- Easy to empty
- Not nice to go outside when you are sick
- Attractive design
- Participate in research to help provide new options for the community (chief in Mafunze)

At the 9 RDP homes that were still using an indoor system (3 having resorted to home built outdoor latrines that preferred to continue having their toilet outside of the house) 5 respondents expressed that they would rather have had the toilet outside because of the concern that the toilet will eventually smell as the previous HS system did. While an indoor toilet is convenient in many ways, when located in a small one room dwelling which may have several occupants, problems of privacy and smells may arise which may make locating the toilet outside preferable.

Of the 10 households using pit latrines, 3 opted to build the new toilet inside (one in a garage to be converted to a bathroom, one in an outbuilding where users live in adjoining rooms and one in the house) while 7 preferred to locate it outside. For three of those who chose to install the toilet outside the reason was that there was not space for the toilet inside. Eight of the pit latrines (4 of 5 VIPs and 2 of 3 home built latrines) are still in use concurrently with the pour flush, sometimes used as an extra toilet when there are a lot of visitors.

Responses when asked what they like about the pour flush included:

- No smell (4 outdoor units, former pit latrine users; 2 indoor units, former HS users)
- Safe for children (2 outdoor units, former pit latrine users)
- Nice to not have to go outside to use the loo in rainy weather (1) or when you are sick (1) (2 indoor units, former pit latrine users)
- No blockages (1 former low flush user)
- Better pit design

Responses when asked what they don't like about the pour flush included:

- It sometimes smells (2 indoor systems, former low flush users)

- It is not nice to see the faeces in the bowl after you defecate (1, former low flush user)
- They would prefer to not have to flush after urinating, but that is not possible (due to smell?)
- The toilet needs to be cleaned every time you use it (1)
- Children cannot pour flush without assistance (1)
- Children forget to flush, leaving toilet soiled (1)

When asked if, having used the pour flush system for several months, there was anything they preferred about their previous system, one former HS user said she preferred the HS seat, while two households with VIPs said they are still very satisfied with their VIPs as well. One respondent said that the outdoor structure built for the pour flush is too small to accommodate some family members. One said that flushing an HS system was more convenient than pour flushing the new system. Respondents reported that their visitors and neighbours liked the pour flush and several (5) expressed that they would like to have a pour flush as well, while two said that thought it would have been nicer to have the toilet built outside because of the common problem experienced with the HS system with unpleasant smells. When asked whether the fact that the pour flush is a new and unfamiliar technology ever resulted in embarrassment because residents would have to explain to visitors how to use the toilet, respondents indicated that it had not been a problem, although children sometimes failed to flush the toilet. One respondent with a converted low flush system in a one room RDP house said that privacy is not a huge issue, but it would be nicer to have the toilet outside, especially if someone has diarrhoea which then makes the house smell.

4.5.4 Use of toilet paper / newspaper for anal cleansing

Table 4.4 Anal cleansing material used with previous system and with pour flush system

	Anal cleansing material used with previous system				Anal cleansing material used with pour flush system		
	Toilet paper	Newspaper	Both		Toilet paper	Newspaper	Both
Former pit latrine user	20%	30%	50%		70%	10%	20%
Former HS user	66%	0%	33%		100%	0%	0%

A clear distinction can be seen between the households which previously had a pit latrine and those which had an HS system in terms of type of anal cleansing material used. While 80% of ex-pit latrine users used newspaper at least some of the time, with only 20% using toilet paper exclusively, among ex-HS users only 33% used newspaper part of the time and 100% used toilet paper at least some of the time. HS users were instructed at the time that their HS systems were installed to use only newspaper. This is clearly a financial burden which some families cannot bear and ultimately a toilet needs to be able to handle newspaper. When pour flush systems were installed, householders were provided with an initial pack of toilet paper to encourage toilet paper use but were also instructed on how to flush newspaper if they needed to use it. Three households have now begun to use newspaper as they cannot afford toilet paper. All of these are former pit latrine users. They have not experienced problems, although sometimes an extra flush is required. Households with HS systems were already accustomed to buying toilet paper and may be able to sustain this more easily that households which had pit latrines. One respondent indicated that she cannot afford toilet paper but is afraid to try newspaper in case the system blocks. Estimates of toilet paper usage ranged from 1 to 4 rolls per person per month at a price of R0.75-R2 per roll. It appears that typical behaviour that might be expected over the long term is that a household will purchase a pack of 10 rolls for R10 at the beginning of the month – regardless of household size – and when it runs out they will use newspaper for the remainder of the month.

4.5.5 Water usage

Half of the respondents indicated that they flushed with 1 litre of water, with 33% flushing with up to two litres. Those with a long sewer flushed with 2 litres or occasionally more (2 jugs). One user consistently flushes with 4 or more litres, insisting that this is necessary although she has not tried flushing with less.

Table 4.5 Amount of water reported to be used for flushing pour flush

Flush amount	1 litre	1-2 litres	2 litres	2-4 litres	Not sure
% of respondents	50	11	22	11	6

Significantly, none of the respondents indicated a problem with having to keep water available in order to be able to flush. A slip up in providing water could potentially result in embarrassment if a visitor discovers after defecating that water must be poured to flush and the bucket is empty. One respondent said that this sometimes happens within the family but that “it’s not a train smash” – the user just calls for someone to bring them water. Some of the outdoor loos are located very close to a tap, and so the user just fills the jug from the tap for each flush. One household does not have any water supply on the property and relies on fetching water from a neighbour’s tap, but no difficulties have arisen so far regarding having adequate flushing water for the toilet. The RDP houses in Siyathuthuka typically have a tap (and shower) in the loo, unlike the RDP houses in France, so flushing water does not need to be stored in the loo, although residents reported that the municipal water supply is sometimes turned off.

In September, 2010, the households with the first two test toilets were requested to monitor their water consumption for flushing for one month. During the first month of use, Household 1, consisting of 3 adults (2 at work during week) reported using 540 litres of water, using 1.5 to 2 litres per flush. Household 2 reported water consumption during the first month as 210 litres. This house has 2 working adults during the week and 4 adults on weekends, using 1.5 litres per flush. In October 2011, two households in the France area, each with two adult residents, were requested to monitor water usage, however the documentation by the householders proved unreliable.

4.5.6 Disposal of solid waste and greywater

Table 4.6 Reported disposal of solid waste and greywater

Disposal of solid waste		
Municipal collection	Burn or pit	Toilet
42%	63%	0%
Disposal of greywater		
Drain	Garden	Toilet
21%	84%	16%

All respondents indicated that they do not use the toilet for disposal of any other waste. The three households in Azalea reported that municipal waste collection is functional in their area, although two of these also burn their rubbish. The five households in Richmond have a rubbish collection service. Other households typically burn their solid waste (7) or dispose of it in a pit or pit latrine. One reported recycling glass bottles. Four of the households (21%) have a drain where household greywater can be disposed of, one having constructed a channel and pit themselves; the remaining 15 households (84%) dispose of greywater outside. Three use some greywater to flush the toilet but do not use the toilet exclusively to dispose of greywater; they do not use dish water in the toilet.

4.5.7 Care of the toilet

Because water does not sit in the pan of the pour flush as is the case with a standard full flush toilet, the research team had some concern that the toilet might soil easily and require frequently cleaning. In general, the toilets have been found clean and well cared for on monitoring visits. Since householders are not contacted prior to visits, they do not have the opportunity to clean the toilets before the researchers arrive. When asked how often the toilet is cleaned, responses ranged from every time someone defecates (6%), daily (11%), 2-3 times per week (33%) to when needed (28%). Twenty-eight percent of respondents were unable to answer this specifically as another member of the household was responsible for cleaning but indicated that the toilet does not become soiled quickly. One respondent indicated that the toilet stays clean if it is flushed immediately after defecation, but when children forgot to do this it needed to be cleaned with a brush. It appears that although the toilet does not have water sitting in the pan, a one litre flush usually cleans the pan adequately of faeces.

Table 4.7 Reported cleaning of toilet

Frequency at which toilet is cleaned				
Every time used	Daily	2-3 times/week	When needed	Don’t know
6%	11%	33%	22%	28%
Products used to clean toilet				
Handy Andy/Harpic	Soap	Bleach	Water	Don’t know
39%	11%	6%	6%	39%

Respondents indicated that they use Handy Andy or Harpic (39%), soap (11%), bleach (6%) or plain water (6%) to clean the toilet. Thirty-nine percent of respondents didn’t know what was used to clean the toilet as another member of the household took responsibility for cleaning.

4.5.8 Success of toilet in preventing contact with faeces

When asked if a bucket is still used by any family member during the night or at other times, 4 respondents indicated that a bucket is used only for urine during the night. Two of these respondents were from one room RPD homes with an indoor toilet. When asked if children ever defecate outside, only one respondent indicated that they do, while the others reported that children only use the toilet or that there are no children in the household.

The lack of provision of a drain for greywater for RDP houses results in dumping of greywater outside. As greywater that has been used for washing nappies or clothes soiled with faeces may be dumped on outside surfaces where householders may come into contact with pathogens that may still be viable, this may represent a risk to householders.

4.5.9 Other roles of toilet in home life

When asked about other purposes the toilet serves in the life of the household in addition to sanitation, 10 respondents indicated that they use the loo for storage (towels, underwear and shoes, tools, buckets and basins, cleaning supplies). Nine of these were one room RDP houses, where the small loo is the only space separate from the main room. Nine respondents indicated that they sometimes use the loo for other activities, such as thinking through problems (4), reading the newspaper (2), relaxing (1) or having private telephone calls (1).

4.5.10 Performance of pour flush system over time

As indicated earlier in the report, the only blockage experienced to date in any of the 20 pour flush systems in the 22 months since the first two became operational was a blockage of the sewer by a plastic packet that had been flushed. Respondents indicated that there have been no problems with flushing.

An inspection of the junction boxes at Household 1 at 13 months of operation also showed that there is no build up developing in the sewer and the system appears to be working well at all points.

Figure 4.35 Soak pit (left) and first junction box (right) after 13 months of use

4.5.11 Pit filling rates

At the end of the project, measurements were taken of the sludge depth in the seven of the soak pits in the study. Sludge depth was measured at the four corners and in the middle of the pit.

Measurements were as follows (in mm):

Household 1

170		**170**
	270	
200		**160**

Household 3

300		**260**
	300	
330		**280**

Household 4

142		**130**
	155	
140		**150**

Household 14

300		**330**
	390	
290		**330**

Household 15

180		**170**
	190	
170		**190**

Household 12

490 water level

Household 16

180 **180**

210

130 **300**

The measurements have been summarised in Table 3.1 below. The median number of users is 4 and the median sludge accumulation rate is 33.5 litres per person per year. This is similar to the rate observed by Norris in his 2000 study of sludge accumulation in septic tanks[5]. It is notable that at one of the homes (No. 4) the accumulation rates are substantially greater than at the other five. In the case of this family (accumulation rate 57 litres per person per annum) they report that they use four litres to flush. It is possible that the pit is partly flooded and that the sludge depth has been incorrectly measured. Measurements at this site should be checked.

The soak pits built for the pilot study have internal dimensions of 1 m by 0.8 m. The height at which the pipe enters the pit varies according to the site topography and the distance from the toilet to the pit, but it is typically 0.3 to 0.4 metres below ground level. The depth of pit below the pipe is typically 0.6 to 0.7 metres, meaning that the sludge will reach the level of the pipe in 3 to 4 years. It is probable however that the sludge breakdown (digestion) rate will increase with time which will effectively extend the pit life by a year or two. When full, the pit must be emptied or the waste must be diverted to the second pit.

[5] The WRC Report, *Sludge Build Up in Septic Tanks, Biological Digestors and Pit Latrines in South Africa* (Norris, 2000) recommends that the filling rate of 29 litres/capita/annum is 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 (i.e. almost identical to the range found with pit latrines).

Table 4.8 Estimated soak pit filling rates for seven households

Household	Years in use	Amount used to flush (litres)	Estimated household size	Average depth of sludge (mm)	Estimated filling rate litres/yr	Estimated filling rate/person/year (litres/person/year)
1	1.29	2	4	194	120	30
3	0.90	1	7	294	261	37
4	1.00	4	2	143	114	57
14	0.67	2	10	328	392	39
15	1.08	1	4	180	133	33
12	1.00	1	2	Filled with water	–	–
16	1.00	1.5	6	200	160	26
Median	**1**	**1.5**	**4**	**197**	**146.5**	**35**

4.6 Conclusions

For the 20 households included in this study, the pour flush model has proved a welcome upgrade from an outdoor latrine or a failed indoor system. It cannot be presumed that a family will prefer to have their pour flush toilet inside, however. While the advantages of having an indoor toilet are obvious, the disadvantages may not be as obvious to those involved from the outside. When people are sharing a small dwelling, an indoor toilet is likely to result in unpleasant smells in the house even when the system is working well. For those who have had indoor low flush systems which have failed, resulting in very unpleasant living conditions, there may be anxiety around having another indoor system. In addition, for users who have had outdoor sanitation all their lives, it may feel cleaner and more decent to keep the toilet out of the house. Over time, the pour flush system may prove to be more acceptable as an indoor sanitation option if it is found to not smell. The response of neighbours and relatives of the families in this study indicates that in general the technology is considered appealing and desirable.

While it is possible that the pour flush system may succeed best when offered as a desirable upgrade option rather than delivered as basic sanitation which still doesn't measure up to aspirations for full waterborne sewage, it has also proven appropriate in this study for poor households who have limited access to water and cannot always afford toilet paper. Household water from bathing or washing clothes can be used for flushing the toilet even if the municipal water supply is cut off for a few hours. The system appears to be able to function well even if newspaper is used for anal cleansing, provided that it is flushed in small amounts at a time.

In this study the pour flush system has proven robust, with only one blockage experienced as a result of a plastic bag being flushed into the toilet. It has also been found to not soil badly, despite the fact that water does not sit in the pan. If flushing water is not kept on hand, and children are not assisted with flushing, however, faeces left in the pan is not easily rinsed out and the toilet will need to be cleaned with a brush.

By increasing the volume of water entering the pit and limiting the amount and size of rubbish entering the pit, the pour flush system also generates a sludge which can be easily removed by vacuum pumping when the pit is full, in contrast to VIP pit sludge which has proven problematic due to being too dry and full of rubbish to remove by vacuum.

5 MANAGEMENT OF SLUDGE FROM POUR FLUSH SYSTEMS

While it is optimal to manage sludge completely on site, this is not always possible, and maintenance of pour flush systems may therefore involve removing sludge from both the pit and the property. It is important that the removal, transport, treatment and use/disposal of sludge are considered from the outset of sanitation provision. How soon will the pit become full? How will it be emptied? Where will the sludge be taken and what will be its ultimate fate? The equipment, labour, costs and safety measures that are involved in answering these questions need to be worked out up front to ensure that a sanitation system is not designed and installed which ultimately cannot be sustained. The various options for managing pour flush sludge are presented in the diagram below.

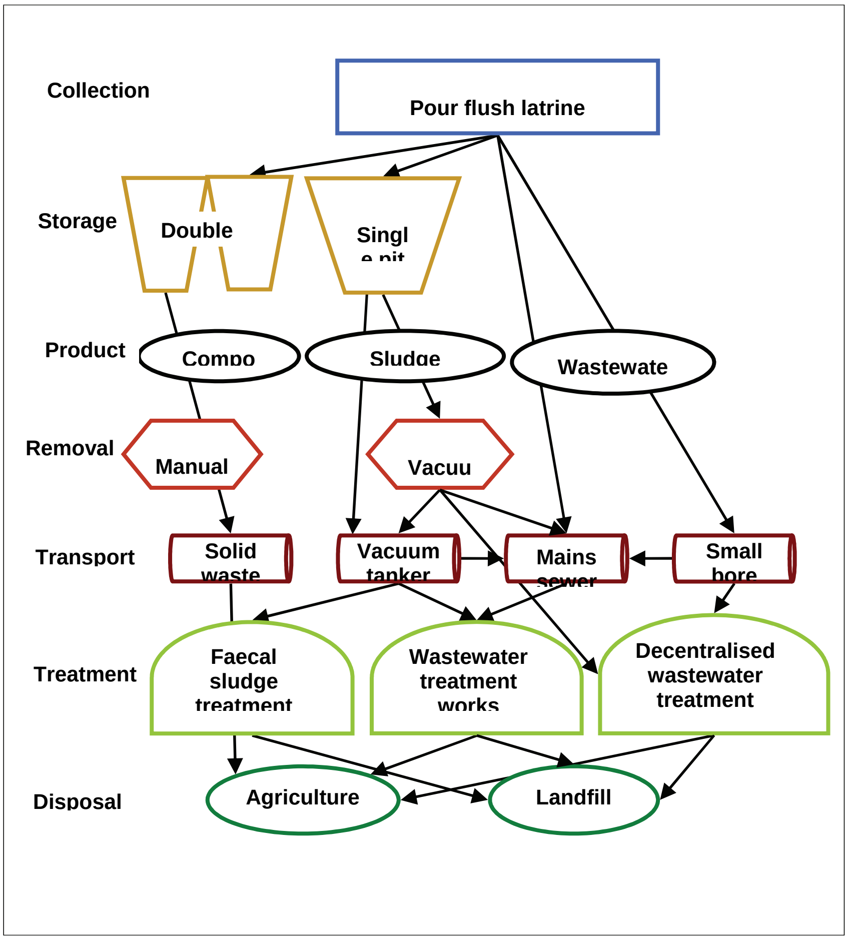

Figure 5.1 Schematic diagram of sludge treatment options for pour flush systems

5.1 Managing sludge on site or off site

Pour flush toilets are typically installed as on-site sanitation systems which use a pit to collect and store excreta. While drainage and decomposition reduce the volume of material which enters the pit over time, eventually every pit will become full. If there is space available, a new pit can be dug and the outlet pipes redirected to the new pit. The sludge in the first pit can then be left to degrade. At that point, it may again be buried on site. If trees are planted over the buried sludge, it may offer one way to recover some of the nutrient value in sludge in order to enhance food security, while eliminating the need for transport, treatment or disposal.

In contrast to VIP toilets, pour flush systems do hold the possibility of connection to small bore sewers or mains sewers. If these options are used, issues of storage and transport are resolved but considerations of the ability of waste water treatment works to handle very concentrated sludge and the fate of the sludge after treatment still remain.

5.2 Characteristics of pour flush sludge

While the addition of flushing water will result in the sludge in the pit of a pour flush system generally being wetter than that in a VIP pit system, the moisture content of the sludge will be determined by a number of variables: to what extent the pit design allows liquids to leach out of the pit, the drainage capacity of the surrounding soil, rainfall, whether urine is diverted from the pit, whether users flush after every use or only after defecation, the amount of water used to flush (systems with longer or flatter sewers sometimes requiring a larger amount of water to flush) and whether users dispose of additional greywater in the pit. Under wetter conditions, degradation in the pit is likely to happen more through anaerobic digestion than aerobic digestion, which ultimately results in slower accumulation of sludge than under dryer conditions; however, the volume of liquid that remains in the sludge and in the pit will contribute to the filling rate as well.

While rubbish is often a significant component in VIP sludge (increasing the filling rate and complicating the removal of sludge when the pit is full) a pour flush system is not conducive to the disposal of solid waste into the toilet and these issues are usually avoided unless the family disposes of rubbish directly into the pit. While no known studies have been done on pit filling rates for pour flush systems, studies indicate filling rates of approximately 40 ℓ/c.a for VIP toilets and 27 to 37 ℓ/c.a for septic tanks.

5.3 Methods of sludge removal

Because of the continuous addition of water to the pit in pour flush systems, sludge which has been in the pit for a few years should be removable with a portable vacuum pump. The large vacuum tankers used by many municipalities can be used to empty pour flush pits as well. However, many households in South Africa are not easily accessible to a large vehicle because of density of housing, difficult terrain or the remoteness of the location. A standard vacuum tanker pumps effectively only if the pit is not more than 4 m below the level at which the vehicle is parked and using a hose no longer than 30 m (Still, 2002).

If the system has twin pits, the contents of one pit are usually left to decompose while the other is filling. This may result in a dryer or denser sludge. If adding water or air to the sludge does not decrease its viscosity enough to pump it, the pit may need to be emptied manually with shovels and rakes. In the case of large pits which take several years to fill, sludge may also become too dense to remove by vacuum.

Innovative technologies that have been developed to overcome the issues of removing and transporting pit sludge are presented in Appendix F. These are discussed in greater detail in reports published by the Water Research Commission, *Tackling the challenges of full pits: Volumes 1 and 3.*[6]

[6] *TACKLING THE CHALLENGES OF FULL PIT LATRINES Volume 1: WRC Report No. 1745/1/12 ISBN 978-1-4312-0291-1* and *Volume 3: WRC Report No. 1745/3/12, ISBN 978-1-4312-0293-5*

5.4 Utilizing or disposing of sludge

Treatment of pour flush sludge at a waste water treatment works is typically not a viable option as the sludge is highly concentrated and the sludge from only a few pits can overload and shut down the works. In addition, there is an increasing problem of what to do with the sludge at a waste water treatment works once it has been treated. Increasingly, international trends are moving towards a view of sludge as a resource rather than a waste, and looking at options for recovering the nutrients and energy it contains, rather than disposing of it. In South Africa, some of the innovative options that are being developed for untreated pit sludge include deep row entrenchment of sludge in commercial forests, which is currently being tested in a Water Research Commission study, and pelletizing of sludge for fertilizer, an option which has been developed by eThekwini Metro Municipality. These and other options are discussed in the Water Research Commission report *Tackling the challenges of full pits* mentioned above.

6 CONCLUSIONS

Pour flush systems have for several decades been the standard basic sanitation system in Asia. While the South African context is different – the most significant difference being the preference for a pedestal over a squat plate and the use of toilet paper and newspaper rather than water for anal cleansing – the strong desire on the part of many South Africans to have a flush toilet rather than a pit latrine motivates the search for an option which requires little water and does not require sewers, large amounts of water and waste water treatment plants.

Low flush systems which have been installed to date in South Africa have had mixed success. A complex relationship exists between system design, service delivery, user behaviour, user perceptions and the political and social aspirations of users. A frequently voiced complaint is that the toilet has an unpleasant smell, which may not be due to system failure alone but also due to the fact that many homes are very small with a large number of inhabitants: indoor sanitation of any type might be found unsuitable in some circumstances. While system failure is sometimes related to design or poor quality parts, the fact that these technologies were never rolled out on a large scale has meant that users have been stuck with a design with non-standard parts which they cannot source. Ambitious design elements intended to aid digestion of sludge may have backfired because of design flaws or because user behaviour was incompatible with more vulnerable aspects of the design, or a combination of both. From an operational point of view, the review of low flush systems currently in use points out that a simple, robust design relying on good quality, standard parts which are easily sourced is likely to stand the best chance of success in South Africa. In additional, it must address the social, political and economic needs of users in terms of users having a say in selecting a technology which is appealing, financially sustainable and compatibility with home life. Finally, the system must interface with municipal sanitation management in terms of pit emptying programmes and supply of parts.

The prototype developed for this project was designed with these principles in mind, eliminating the problems frequently associated with a cistern and unreliable water connection, utilizing a water seal rather than a mechanical seal or using the sludge itself as a seal, and aiming aesthetically to be as similar to a standard flush toilet as possible. In this study the pour flush system has proven robust, with only one blockage experienced – caused by a plastic bag being flushed into the toilet – occurring at any of the 20 units that have been installed over the first 22 months. The pedestal has also been found to not soil badly, despite the fact that water does not sit in the pan. Household water from bathing or washing clothes can be used for flushing the toilet even if the municipal water supply is cut off for a few hours. The system appears to be able to function well even if newspaper is used for anal cleansing, provided that it is flushed in small amounts at a time. It is anticipated that pits will fill over approximately 5 years and that it will be possible to remove the sludge with a vacuum tanker because of the reduction in solid waste and increase in moisture content over VIP sludge.

For the 20 households included in this study, the pour flush model has proved a welcome upgrade from an outdoor latrine or a failed indoor system. It cannot be presumed that every family will prefer to have their pour flush toilet inside, however. Over time, the pour flush system may prove to be more acceptable as an indoor sanitation option if it is found to not smell. The response of neighbours and relatives of the families in this study indicates that in general the technology is considered appealing and desirable.

While it is possible that the pour flush system may succeed best when offered as an upgrade option rather than delivered as basic sanitation which still does not measure up to aspirations for full waterborne sewage, it has also proven appropriate in this study for poor households who have limited access to water and who cannot always afford toilet paper.

This technology can be taken to scale provided that a manufacturing partner can be found to produce the pedestal at a price comparable to a VIP pedestal.

7 RECOMMENDATIONS

The pour flush system developed during this project has proven successful in households with a history of both low flush and VIP sanitation over the monitoring period of this project. The following recommendations are made to ensure that this technology – which represents a potential solution to both householders and municipalities – is given the strongest possible opportunity to succeed:

1. **Promote the pour flush system to municipalities which are considering implementing waterborne sanitation or which need to replace failed low flush systems.** Municipalities are under pressure to move to waterborne sanitation, but in most cases have neither the water nor the funds to make this feasible. Pour flush is a step up the sanitation ladder between the VIP and full flush sanitation, and may possibly provide a way forward. The uMgungundlovu District Municipality has several thousand dysfunctional low flush toilets in various settlements under its authority, and is probably a likely candidate to take this technology to scale. It is imperative that wherever the system is rolled out by a municipality that replacement pedestals are made available to local hardware shops and plumbers so that householders are able to repair their systems as needed (but see point 5 below).

2. **Promote the pour flush system to municipalities as an optional upgrade which householders can pursue at their own expense.** Where municipalities have opted to provide VIPs for basic sanitation, the pour flush system could be promoted as an optional upgrade, available to householders at their own cost. If the system is introduced in this way there would be a sense of ownership and a willingness to do what is needed to make the technology work. If, however, pour flush is introduced with no option, there will inevitably be those who may argue that is a second-rate flush toilet. If those with pour flush have paid a little extra to have this form of sanitation, it is likely that it will become a status symbol and this will promote its uptake.

3. **Continue to research and monitor the success of the pour flush model where it is implemented.** Most of the 20 trial units have been in operation for just one year. While their success so far is encouraging, it is arguably still too short a time for absolute confidence that this is a successful sanitation technology. Ongoing monitoring and evaluation and ongoing monitoring of pit filling rates is advisable. PID will make follow up visits after another 6 and 12 months, and will publish the results.

4. **Study the degradation of sludge in pour flush soak pits over time.** While it can be assumed that pour flush sludge will have a higher moisture content and more homogeneous character than VIP sludge, the qualitative changes in pour flush sludge over time remain to be seen. How fast will it accumulate? How much will it stabilise? What processes occur within the pit and in the surrounding soil in terms of the action of soil fungi and other biota on the sludge and liquids seeping out of the pit? Will sludge left in the first pit of a twin pit system remain wet enough for removal by a vacuum tanker after the second pit has filled? Will pour flush sludge be wet enough to be processed as fertilizer pellets, an option eThekwini Municipality has developed for utilizing VIP sludge which could be expanded to pour flush sludge if appropriate? Sludge characteristics and conditions in the pit should be monitored over the first life cycle of the pour flush systems built for the pilot study in order to enable accurate calculations of pit filling rates, required maintenance cycles and for final utilization of sludge.

5. **Study the impact of pollutants from the sludge on the surrounding soil and water table.** To what extent are metals, nutrients and pathogens contained in the sludge carried out of the pit into the surrounding soil? Is there any impact on groundwater or nearby water sources? At what point in the lifecycle of a pit is impact on the environment greatest? What is the fate of pathogens in the sludge over time? Investigating these issues over the lifecycle of the first pour flush units will provide a

better understanding of the conditions, such as soil type, slope and depth of the water table, under which pour flush systems function optimally and conditions under which extra measures may be required to prevent contamination of the environment.

6. **Find an industry partner to fabricate pour flush pedestals at scale.** The pedestals used for the research and development have been made from fibreglass. Fibreglass is relatively economical to work with for prototype development, as without any major capital investment it can be incrementally modified until the prototype is suitable. The disadvantage with fibreglass is that it is relatively expensive compared to plastic and porcelain, which means that it will not be suitable for mass production. In order to produce a pour flush pedestal in porcelain or plastic a manufacturer will have to invest several hundred thousand rands in mould development and production. This is unlikely to happen unless the manufacturer has confidence that a market exists for the product. This is something of a chicken and egg situation. If one fair size (i.e. several thousand unit) pour flush project is implemented, then that will provide the impetus to get a competitively priced pedestal to the market.

7. **Investigate the modification of this model to a low flush model to be used in schools and other public spaces where a pour flush system would not be appropriate.** The existing pour flush design relies on flushing water to be kept available and to be used when necessary in order to keep the system clear and operational, requirements which are unlikely to be met consistently in a public toilet context, making the system prone to failure. It may be possible to modify the system, keeping the essential design elements which have proven successful, to develop another prototype appropriate to public environments.

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Appendix A: Survey of low flush sanitation systems

Survey ____ House # ____ Male / female HS / DSA Indoor / outdoor

A. History and technical performance

1. History with toilet
   Year toilet built ____ Previous toilet still here? Y / N Family size ____ Any: children /elderly / infirm

2. What has worked well with your low flush toilet and what problems have you had?
   Are these still working: 35 L reserve water tank (outside) Y / N , cistern (inside) Y / N ,
   flusher Y / N , pedestal and pipes Y / N , liquefier tank Y / N , soakpit Y / N
   Comments: ____________________
   Have you had any blockages? Y / N
   What do you think caused them? ____________________
   Breaks? Y / N ____________________ What caused them? ____________________
   What did you do? ____________________
   Could you find parts/plumbers when you needed them? Y / N
   Any other problems? Comment: ____________________

3. Any suggestions for improvement of design? ____________________

4. Has your soakpit gotten full yet? Y/N Did you get it emptied? Y/N Who emptied: ____________ Cost? ____ Satisfied? Y/N How much would you pay for better service? ____

B. Acceptance and convenience

5. How did you feel about getting a low flush toilet at first? Do you still feel the same?
   Feeling at first ____________________ Feeling now ____________________

6. What kind of toilet did you have before? ____________________
   Any ways the low flush toilet is better than your old toilet? ____________________
   Any ways your old toilet was better? ____________________

7. What do relatives or friends think about it that don't have a pour flush?
   ____

8. Is there anything about the toilet that embarrasses you when you have visitors?
   ____

C. User behavior

Flushing:

11. What do you use for cleaning yourself? Toilet paper / Other: ____________
    What did you used to use? ____________
    If toilet paper: How much do you spend per month? ____________
    If other materials: how/where do you dispose of them? ____________________
    If flush: has this led to blockages or other problems? ____________________

12. If flusher is broken, how do you flush? ____
    How much water do you use to flush? ____ If more than 1 l, why? __________________________
    Where do you get your flushing water? ____
    Do you use any household waste water for flushing? Y/N dishwater/ bathwater/ clothes washing water
13. What do you use to clean the toilet? ______________?
    Unblock the toilet ______________________?

Success of the pour flush in reducing household contact with faeces:

14. Do you have a bucket or another system that you still use in the house at night, for some family members, or in certain situations? Y/N Only for urine or sometimes faeces too? Urine / faeces too
    How /where do you empty it? ______________
15. Do children always use the toilet or sometimes poo outside? Always toilet / sometimes outside

Role given to pour flush in overall household disposal of waste:

16. Where do you dispose of rubbish like nappies, glass bottles, menstrual cloths now? ______________
    Are you satisfied with this? Y / N Do you every put any of it directly into the soakpit? Y / N
17. Where do you dispose of household wastewater? ______________ Is this satisfactory? Y / N

Role of the toilet in meeting other household needs:

18. Do you spend time in your toilet for reasons beside bodily functions (e.g. A place to be alone, think, read, pray)? N / Y: ____
19. Do you use the toilet for anything else (e.g. storage, animals)? N / Y: ______________________________
20. Do you still use your old toilet for anything? N / Y: ____

<u>Researcher observations:</u>

Smell? **Issues for photographing?**

Check inside liquefier. Working Y/N **Any signs of problems around pit?**

Other comments:

Appendix B: Health education poster

Appendix C: Pour flush user assessment and evaluation survey

Family name ________________________ Area _________________________

A. History

Family size________ Gender and age of respondent _____________ House number ____________

1. What kind of toilet did you have before? How did you get it? When?

2. What worked well with your previous toilet and what problems have you had? Other family members? Issues with going outside?

3. Has your soak pit gotten full before? What did you do?
   - Who emptied and how, problems
   - Problems with emptying
   - Fee charged and acceptability of service, willingness to pay – and how much – for better service

B. Acceptance and convenience

4. Why did you want to have the pour flush toilet installed?

5. Which things do you like about the pour flush? Anything you don't like?

6. Anything about old toilet you liked better?

7. What do relatives or friends think about your new toilet?

8. Do you have to explain to visitors how to use the toilet? Is this embarrassing to you or them? Have you had any problems … e.g. guests use the toilet and there was no water left for flushing?

C. Performance

9. Have you had any problems with the pour flush? What did you do?
   Blockages? Flushes ok?

D. User behavior

Flushing:

10. What do you use for cleaning yourself? What did you used to use?
   a. If using toilet paper: How much do you/did you spend per month? Comments.
   b. If other materials: how/where did/do you dispose of them? If flush: has this led to blockages or other problems

11. How much water do you use to flush? If more than 1 l, why (e.g. It stays soiled otherwise, it doesn't flush well). Where do you get your flushing water? Do you use any household waste

water for flushing? Do you store water in the loo or fill a jug at the tap for each flush? How do you handle this with guests?

12. What do you use to clean and unblock the toilet (e.g. products that might impact processes in soakpit)?

13. How often do you clean the toilet?

Success of the pour flush in reducing household contact with faeces:

14. Do you have a bucket or another system that you still use in the house at night, for some family members, or in certain situations? Only for urine or sometimes faeces too? How /where do you empty it?

15. Do children always use the toilet or sometimes poo outside?

Role given to pour flush in overall household disposal of waste:

16. Where do you dispose of rubbish like nappies, glass bottles, menstrual cloths now? Are you satisfied with this? Do you ever flush it?

17. Where do you dispose of household wastewater (toilet?) Is this satisfactory?

Role of the toilet in meeting other household needs:

18. Do you spend time in your toilet for reasons beside bodily functions (e.g. A place to be alone, think, read, pray)? Is this a change from how you used your previous toilet?

19. Do you use the toilet for anything else (e.g. storage)?

20. Do you still use your old toilet for anything?

Appendix D: Pour Flush Monitoring and Evaluation Results

HISTORY						
Household no.	**Area**	**Family Size**	**Gender/age of respondent**	**Comments on home**	**1. Previous sanitation**	**2. Built by**
1	Azalea	3	F, 38?	Home built	VIP	Municipality
2	Azalea	4	F, 38	Home built	VIP	Municipality
3	Azalea	7	M/24	Home built	VIP	Municipality 1yr ago
4	France	10	F, 54	Homebuilt wattle and daub 3 room	Home built	Self
5	France	3	M, 19	Wattle and daub home, garden well cared for	Home built (removed HS)	Self
6	Mafunze	7	M/35	7 room home, outdoor rondavel, neat	VIP	Municipality
7	Mafunze	5	M	Home built compound with several buildings	2 VIPs (1 converted to PF), indoor full flush)	2007 for both
8	Mafunze	5	F	Shop w/ family living above	VIP	20 years,unsure who
10	Siyathuthuka	?	M	RDP	Home built	Self
11	France	7	F/31	1 rm RDP	Homebuilt: removed HS	Self
12	France	6	F/48	1 rm RDP, rubbish around garden	HS	Municipality, 1999
13	France	2	F/61	neat, basic	HS	Municipality, 10 yrs
14	France	4	36	1 room RDP	HS	Municipality, 2001
15	France	9	F, 42	RDP house extended to 4 rooms.	HS	Municipality
16	France	2	F, 23	RDP 1 room, very neat, some veg	HS	Municipality
17	Siyathuthutka	1	M, 25?	RDP 1 room, very neat	HS	Municipality
18	Siyathuthutka	5	F, 47	RDP house extended.	HS converted to full flush	Municipality
19	Siyathuthutka	3	F, 58	1 room RDP	HS	Municipality
20	Siyathuthutka	5	F, 32	1 room RDP	HS converted to DSA	Municipality
SUMMARY	**F: 8, A: 3, M: 4, S: 5**	**Range: 1-10, Mean: 5**	**13F, 6M**	**Home built: 8, RDP: 11**	**VIP: 6, homebuilt: 4, HS: 9, DSA:1, full flush: 1**	**M: 12, self: 6, unknown: 1**

HISTORY					
3. Pros and cons	**4. Anal cleansing**	**5. Soak pit filled**	How emptied	Problems with emptying	Fee charged. Acceptable?
Old	Both	Yes, moved	n/a	n/a	n/a
Old	Toilet paper	No	n/a	n/a	n/a
Was getting full of water. No problems going outside.	Toilet paper	With water	n/a	n/a	n/a
Floor breaking, afraid of falling into pit.	Newspaper	No	n/a	n/a	n/a
HS pit too shallow, never used	Newspaper	Yes, built new toilet	na	na	na
No problems: previous homebuilt used to leak w/ rain wetting seat and t.p.	Both	No	n/a	n/a	n/a
Didn't like that the VIPs didn't flush	VIP - newspaper, flush - tp	No	n/a	n/a	n/a
No problems	Newspaper	No	n/a	n/a	n/a
Overlooked by municipality during service delivery	Both	No	n/a	n/a	n/a
HS smelled, took it out.	Both	Full now	n/a	n/a	n/a
Blockages and smell	Both	2007, dug a pit behind the house for burial	Yes, emptied using buckets	couldn't empty to the bottom with buckets, only emptied halfway, had no protective equipment	none
Smelled in hot weather, couldn't clean flap, flap broke off, cistern broke, pit filled and toilet blocked	Toilet paper	Yes, filled and blocked	PID emptied now	n/a	n/a
After 3 years stopped flushing, had to use neighbour's toilet	mostly tp, some newspaper	Yes, not emptied because PID built new soakpit	n/a	n/a	n/a
Full pit, blocked, smelly, insects coming down from cistern	Toilet paper	Yes, dug hole	emptied with buckets		no charge
Smelly, blockages	Toilet paper	No	n/a	n/a	n/a
Tipping tray broken off, home built soak pit	Both	No	n/a	n/a	n/a
Manually filling cistern.	Toilet paper	Yes, dug new pit	n/a	n/a	n/a
	Toilet paper	No	n/a	n/a	n/a
Manually filling cistern.	Toilet paper	No	n/a	n/a	n/a
Blockages: 5, smell: 5, broken tray: 3, broken cistern: 4 insects: 2, broken floor: 1	**TP: 8, Newpaper: 3, Both: 8**	**No: 10, Yes: 9; Moved toilet: 2, new pit: 1, removed sludge: 2**	**2: emptied HS w/ buckets**	**1 couldn't empty to bottom**	**No fees paid**

ACCEPTANCE AND CONVENIENCE					
6. Reasons for choosing PF?	**7. Pros and cons of PF**	**8. PF inside/outside. Satisfied?**	**9. Preferred aspects of previous toilet.**	**10. Attitude of visitors to PF**	**11. Difficulties around visitors flushing?**
save water	upgrade	Outbuilding room	No	Like it	no
save water, upgrade	upgrade	Outside -chose	No	Like it	no
Pit full of water; saw neighbour's PF	Safe for kids; no smell	Outside	No	None yet	None yet
Saw it would be safe	No, like the safety	Outside -- ok but one disabled family member	No	Like it	Explain to visitors, no embarrassment. Never unflushed.
easy to empty, impressed with design	no problems, no smell, easy to clean	Chose outside because no space inside	No	Most like it and would like to have one	No problem, obvious how to use.
inconvenient at night and in bad weather.	Convenient when ill; saves water over full flush.	Inside, happy with that.	No, but like VIP too.	Like it	Not a trainsmash! we just call someone to bring some.
To participate in research to help provide new options for the community	No smell because of pouring water	Outside -- used by relatives and tenants living on property	No	They like it a lot	Jug is already there, no problems,
Convenience -- don't like going outside	Like everything	Inside	No problems, still like it	They like it and want one.	We explain, no embarrassment
Wasn't provided w/ toilet before	Like it, too small	Outside	space	Like it but small.	No
Could have it outside -- avoid danger of smell	Not yet used	Outside. Yes.	No	Not yet used.	Not yet used.
Wanted a change because of problems with old system -- visitors no longer wanted to come.	Like it v much, but don't like having to see the shit when you flush. Have to assist children because of pouring. Sometimes smells.	Inside, would rather it was outside	No	Some of them would like to have a pourflush.	Yes have to explain but not embarresing. Problems with kids going repeatedly without flushing. Privacy not a big issue, but outside would be nicer. Small house -- diahrrea smells!
Easy to clean	Like everything	Inside	No	Like it	No problems -- bucket in loo
Needed a toilet that worked	Sometimes smells; seat broke	Inside, Don't like having it inside	Liked the seat better.	They want one; they say that it doesn't smell.	Yes have to explain but not embarresing. Kids sometimes don't flush
wanted improvement	everything, no complaints	Inside	No	__	we explain, no embarrassment, never had a person who didn't flush
it flushes well, told there was no smell	No blockages, dirty every time, don't like to flush after urine	Inside		Neighbours asked us	explain, not embarrassed, no one forgot to flush
Old one had problems	Like it	Inside	No	Like it	No
Old one problematic	Like everything	Inside	No	Like it	Explain, no problem.
Old one had problems	No problems; doesn't flush	Inside	Flushing	Better to have it outside	No visitors

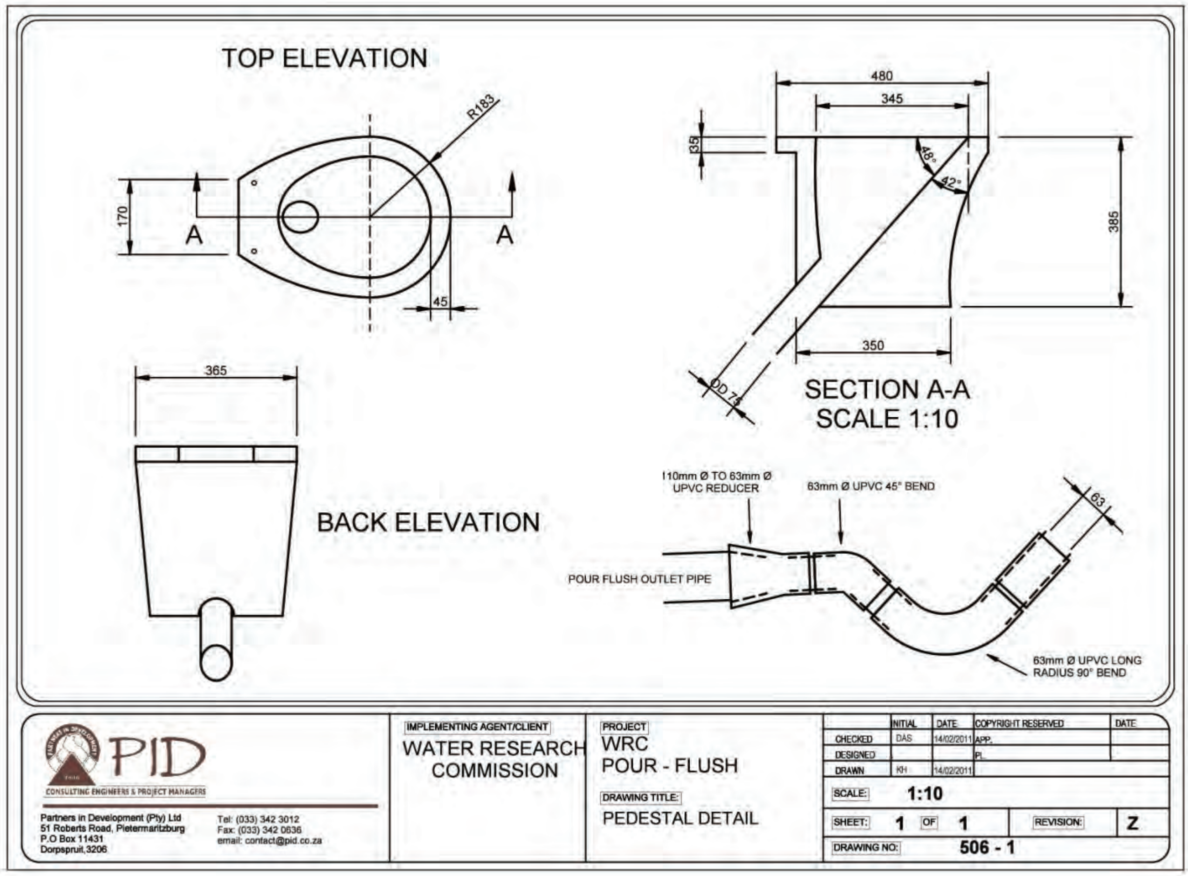
Didn't like old one	Like it , no smell	Inside	No	Like it, some think it should be outside	No problems
Problems w/ old one: 8;	**Like it: 15**	**Inside: 11; Outside: 8**	**14: None**	**16: Like it**	**18: No**

PERFORMANCE			**USER BEHAVIOUR: FLUSHING AND CLEANING**			
12. Problems w/ PF?	**Blockages?**	**Flushes ok?**	**Disposal of other waste. Blockages in toilet?**	15. **Amount of flush water used; source.**	16. **Products used to clean toilet**	17. **How often do you clean the toilet?**
no	Yes	Yes	None	1 litre	Handy Andy , Harpic	2-3x/week
yes	yes	Yes	None	2 litres	Handy Andy	Don't know
No	No	Yes	None	1 litre, keep bucket in loo	-	3x/week
No	No	Yes; sometimes repeat flush for newspaper	None	water from neighbour. 1-2L, no wastewater,	-	When needed
No	No	Yes w/ newspaper	None	1 L, tap nearby.	soap	every few days
No	No	Yes; sometimes flush twice	None	2l, sometimes more because we have bathwater sitting there.	Harpic Clean, Handy Andy	Don't know
No	No	Yes	None	2L, get water from tap.	Don't know	Don't know
No	No	Yes	None	1-2L	Bleach	When needed
No	No	Yes	None	1 litre	-	Don't know
Not yet used.	Not yet used.	Not yet used.	Not yet used.	Not yet used.	Not yet used.	Not yet used.
No	No	Yes -- 1 litre ok	None	1 litre ok. Fetch water from tap outside and keep 20L bucket in loo; no greywater	Nothing - was told not to	Daily
No	N	Yes	None	1 litre, keep bucket in loo	Handy Andy	Daily
No	No	Yes	None	4 litres (2 jugs). No waste water.	Handy Andy	2x/week
No	No	Yes	None	2L, from outside tap, 20L in loo	Handy Andy	2x/week
No	No	Yes	None	1 litre	-	every time they use it
No	No	Yes	None	1 litre	-	Don't know
No	No	Yes	None	1 Jugs (2-4L) (long sewer), greywater	soap	Don't know
No	No	Yes	None	not sure (water from tap)	-	stays clean
No	No	Yes	None	1 litre	Handy Andy	2x/week

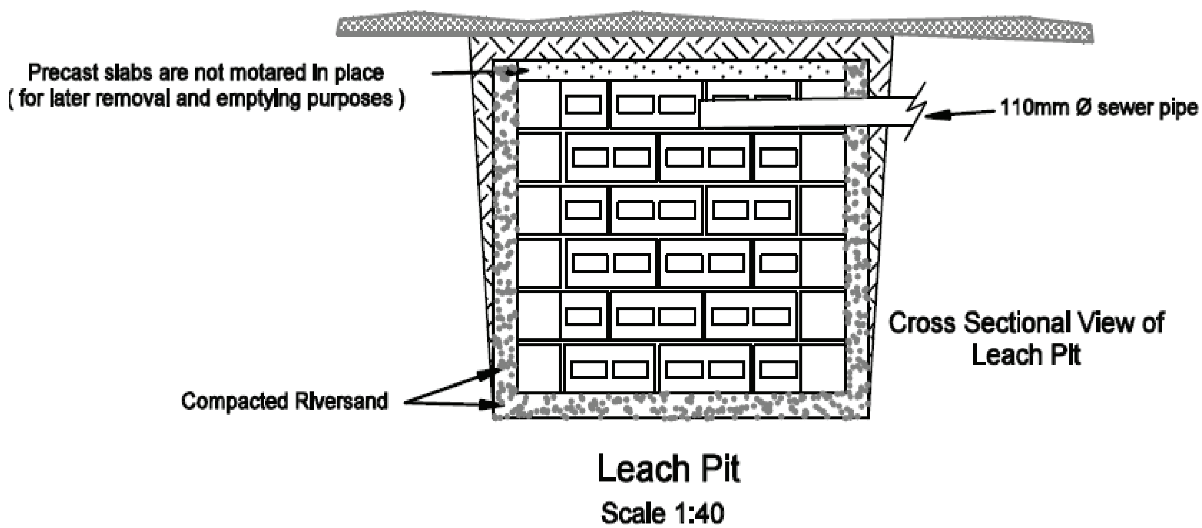
No: 18; Yes: 1	**No: 18; Yes: 1**	**18: Yes**	**18: None**	**1L: 9; 1-2L: 2; 2L: 4; 2-4L:2; don't know: 1**	**HA: 7; don't know: 7; soap: 2; bleach: 1; nothing: 1**	**Every use: 1; daily: 2; 2-3x/wk: 6; when needed: 3; don't know: 5**
CONTACT WITH FAECES		**DISPOSAL OF WASTE**		**HOUSEHOLD NEEDS**		
18. Bucket used concurrently? Urine/faeces?	**19. Outdoor defecation?**	**20. Solid waste disposal**	**21. Grey water disposal**	**22. Social role of the loo?**	**23. Practical role of the loo?**	**24. Use of previous toilet**
No	No	burn and collect	Drain	read newspaper	Yes; bathing	Still in use.
No	No	burn and collect	Drain	read newspaper	No	Still in use.
No	Yes	Municipality collects	Dump outside	No	No	n/a
No -- one adult diapers	No	Burn	Dump outside	No	No	n/a
No	no kids	Burn	Dump outside	privacy for phone calls	No	Still in use.
bucket for urine	No	Old VIP hole; kids sometimes throw into current VIP.	Dump outside, also use it for toilet but not dishwater	Thinking	Yes; cleaning materials, underwear.	Still in use.
don't know -- tenant family	No	Pit for rubbish	Dump outside	No	No	Still in use.
Yes	No	Pit for nappies and bottles	Dump outside	No	No	Still in use.
No	No	Collection	Home made channel	—	No	Still in use.
No	No	Burn	Dump outside	Not yet used.	Not yet used.	Not yet used.
No	No young children	Burn, recycle glass.	Dump outside	To be alone if you have problems	Spades, tools	n/a
No	N/A	Burn only, no collection	Dump outside	Place to relax, no smell	Yes; towels, curtain rods	n/a
Only urine in a bucket at night and throw it outside	No	Burn, no flushing	Dump outside, if it looks clean use it in the toilet	Yes, spend some time to think	Yes; store shoes	n/a
no bucket	no young children	Burn and pit	drain - in new extension	No	Yes; bucket	n/a
No	no children	Burn	Dump outside	I do go there and think	Yes: detergents, bathing basin, bucket	n/a
No	No	Collection	Dump outside	No	Yes	n/a
No	No	Collection	Dump outside	No	Yes	n/a
No	No	Collection	Dump outside	No	No	n/a

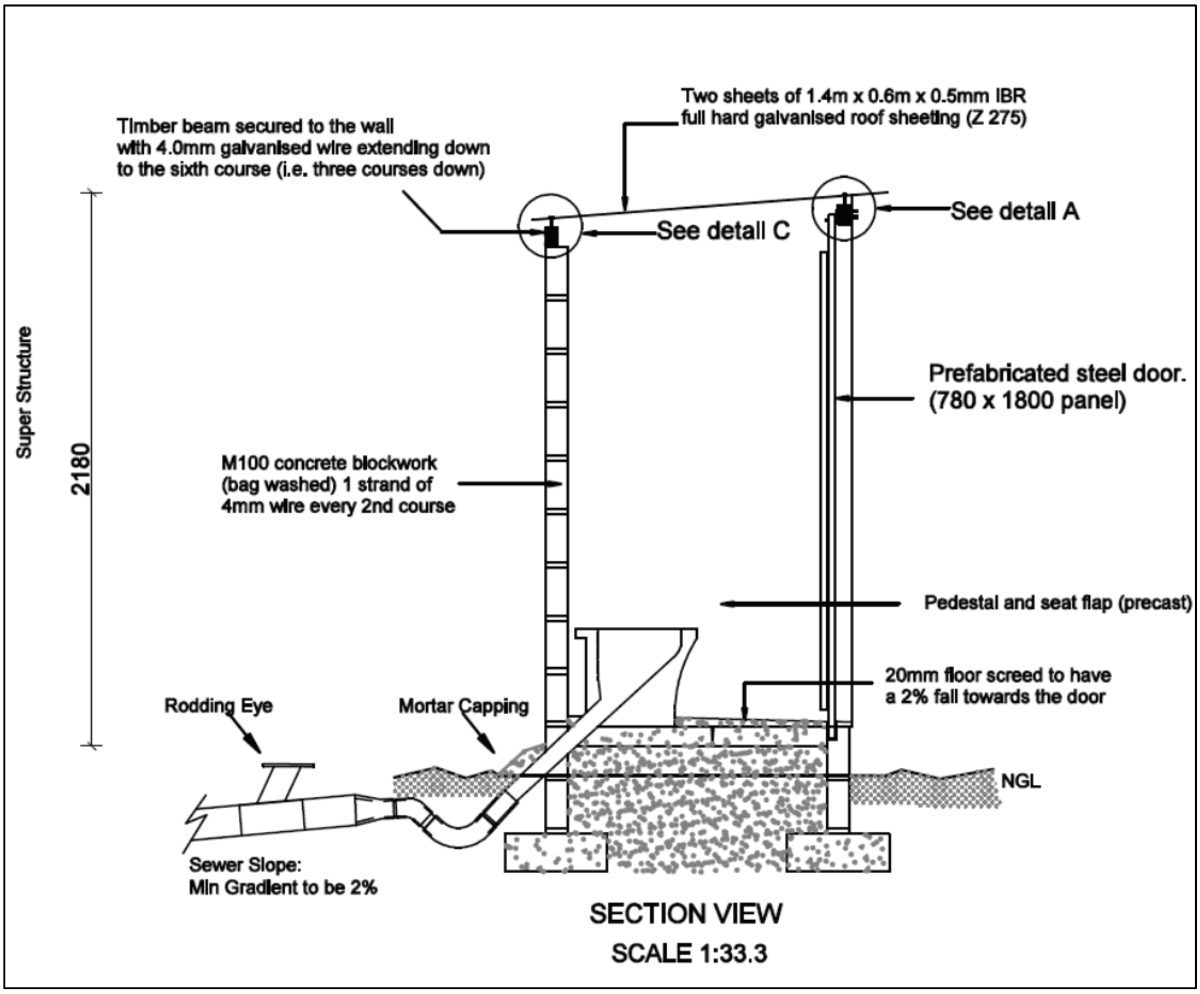
No	No	Collection	Dump outside	No	Yes	n/a
No: 15; Yes: 3; don't know: 1	**18: No; 1: Yes**	**Collect: 8; burn: 9; pit: 3**	**Dump outside: 15; drain: 4; 2 use for flushing**	**No: 9; Yes: 8**	**Yes: 9**	**7: still in use; 11: removed**

Appendix E: Specifications for pour flush pedestal and pit



Pour flush pedestal





Pour flush top structure and sewer

Appendix F: Removal and transport of sludge

Pit emptying technologies

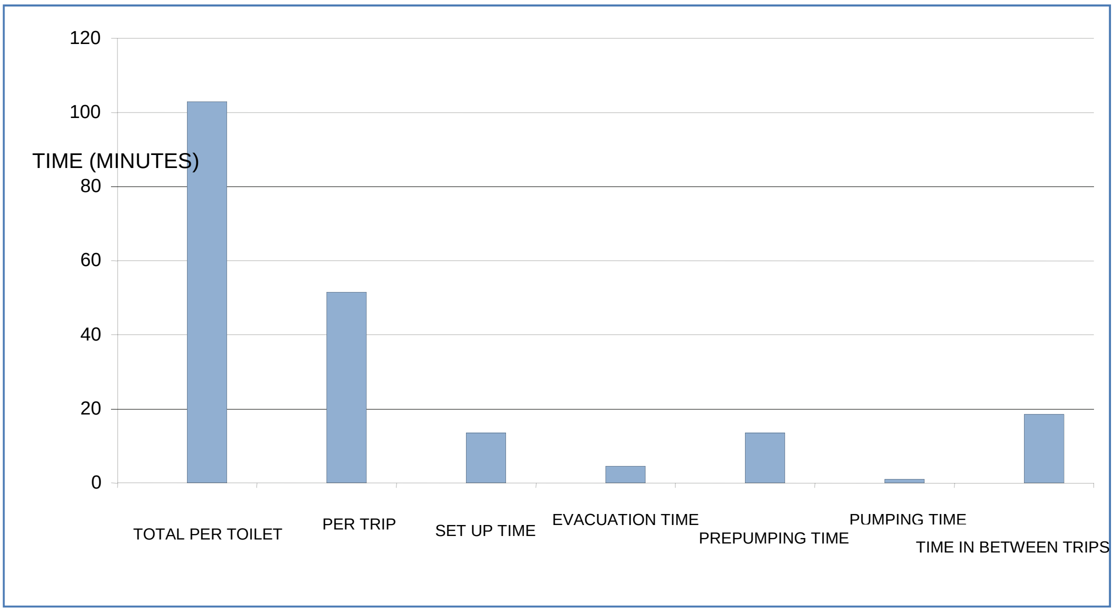
A number of innovative technologies have been tested in various countries over the years to overcome the issues of access to on-site sanitation. Among these are the Vacutug, Micravac, Maquineta, Dung Beetle (all of which are small vacuum tankers (Sugden, 2008)) and the MAPET and the Gulper (which are manually operated vacuum pumps which can be carried by hand to a site, with waste carried away in containers by hand).

Prior to the development of the pour flush system for this project, the project team tested the removal of sludge from low flush HS systems in Slangspruit, Pietermaritzburg with the Vacutug. As the HS systems are designed with a one litre flush, the sludge produced has the same characteristics as the sludge produced in the pour flush systems: the amount of water entering the system would be similar and both would largely exclude rubbish from entering the pit directly, while VIP sludge typically contains rubbish which can easily block a vacuum tanker.

Removing rubbish from a pit with a rake prior to emptying

Although less rubbish was found in the HS soak pits than is typically found in VIP pits, some was still present and removal of rubbish prior to emptying the pit increased the amount of time required. If rubbish was not removed prior to emptying, blockages resulted in as much as 1.5 hours more time being spent emptying the pit. Sludge was dryer in some pits than others. Working with drier sludge could increase the emptying time by 15 minutes or more. It was found that adding 40 to 80 litres of water to the soak pit liquefied the sludge enough to be removed.

The Vacutug (blue) transferred sludge from the pits of low flush systems in Slangspruit to a 5 m^3 holding tank (green) which was later emptied by a municipal vacuum tanker (yellow).



Analysis of time taken to empty 1 cubic metre low flush soak pits at Slangspruit using Vacutug

As part of Water Research Commission Project 1745, Partners in Development has developed two mechanised vacuum technologies. The NanoVac is a piston pump powered by a 5.5 hp IC engine and the eVac utilises a vane pump powered by an electric motor.

The Gulper (left) a hand operated vacuum pump (Sugden, 2008) and the E Vac (right) and electrically powered vacuum pump developed by Partners in Development

As most of these technologies are still under development or are not widely available, municipalities or companies in South Africa servicing pour flush systems with wet sludge at present have few options other than a standard vacuum tanker for removing wetter sludge.

Transport

If access to the site is difficult, it may be necessary to remove sludge in bins or with a small vehicle to the nearest access point for the transport vehicle.

Drumbarrow used by eThekwini (left) and Chinese two-wheeled tractor with trailer transporting bins to truck for road transport (right, UN HABITAT 2009)

Steven Sudgen has developed a faecal waste management system called the trike, which combines manual extraction, manual carting and mechanized hauling.

The trike in use in Dar es Salaam
(Steven Sugden).

The use of transfer stations, which can take the form of large plastic containers or concrete chambers, can significantly reduce transport costs as sludge can be carted manually to a deposit site from which a vehicle can collect it for hauling longer distances.

A number of simplified sewering options have been used which can transport either liquid contents of a pit or all excreta from a pour flush system off of the property. The direct addition of large volumes of pour flush waste to mains sewers designed for full flush waterborne sanitation is likely to lead to malfunction due to the low flow volumes.