DEVELOPING A LOW FLUSH LATRINE FOR APPLICATION IN PUBLIC SCHOOLS

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Background

In the South African context, waterborne sanitation is often perceived as a standard representing equality and dignity to which people without waterborne sanitation aspire. However, in view of the scarcity of water resources, waterborne sanitation for all is a goal which is neither attainable nor desirable. The provision of basic sanitation in South Africa has tended to be characterized by a single technology delivered across a community – typically the ventilated pit latrine (VIP). Imposing a "one size fits all" solution on a community can fuel the frustrations of community members and subsequently aspirations for waterborne sanitation. Also, if residents resent the sanitation systems they have been given they may be more likely to expect municipalities to maintain their systems and be unwilling to take responsibility for repairs and associated expenses to keep their systems in good order themselves. Providing the opportunity for home owners to select between different viable sanitation options restores agency and fosters ownership which in turn promotes initiative to take the necessary measures to keep systems in good working order. In addition, by expanding the range of on-site sanitation options available to municipalities for service delivery and available to home owners as an upgrade which they pay for themselves, the conditions are enhanced to encourage entrepreneurship within communities for conversion of systems and plumbing and maintenance services.

Pour flush and low flush sanitation systems bridge the gap between on-site dry sanitation and full waterborne sanitation sustainably. Using a small amount of tap water or grey water (1-2.5 ℓ) to flush, a pour system can terminate in a simple soak away. This overcomes the problems involved with laying sewers to widely spaced rural homes or tightly spaced informal settlements, represents a large saving of water over regular waterborne sewage – a loss which is compounded if hardware begins to leak – and provides a number of the benefits of a flush toilet.

While pour flush technology is used widely in Asia, it had not been tested in South Africa, and trials with low flush systems had had mixed success. In 2009, on behalf of the WRC, Partners in Development undertook to develop a pour flush system appropriate to the South African context. The pour flush system that was developed was tested successfully in the field at 20 private homes and at a crèche. This technology offers a promising option for domestic sanitation, but to succeed in an institutional setting such as a school or public ablution facility, it would need to include a cistern so that users would not be required to fill buckets in order to flush.

Project scope

This project undertook to modify the pour flush system developed and tested in Water Research Commission Project 1887 to a low flush system with a cistern in order to provide a new option for institutional as well as domestic sanitation. A prototype was developed and tested after which the technology was piloted in two schools and two homes. Once in use, the systems were monitored over three months. User experience and feedback was gathered and assessed.

Methodology

During the development of the pour flush prototype it became clear that two reasons that the pan could be cleared with one litre was that the slope of the pan was very steep and that flushing by pouring water into the system by hand allowed the user to pour with a dumping motion that helped to push the pan contents through the gooseneck. The addition of a cistern and flush mechanism required design experimentation to achieve a strong enough flush with a relatively small volume of water without the benefit of the pouring action. As with standard flush toilets the flush had to be introduced by the rim of the toilet in such a way that the pan both emptied and self-cleansed. The design was tested using a standard protocol for full flush toilets and proved successful in flushing simulated faecal samples and toilet paper with 2 litres, and simulated faecal samples and newspaper with 2.5 litres. After testing, fibreglass pedestals were produced and 3 were installed in each of 2 schools. A health and hygiene presentation was made to learners and staff at both schools and educational materials were distributed to those in attendance. In addition, pour flush systems that had previously been installed in 2 private homes were converted to low flush systems. The low flush toilets were monitored for 2-3 months during which time all 8 units performed well and experienced no blockages or other problems. Meanwhile prototype development is being carried out by the plastics moulding company Envirosan for production by injection moulding. This requires some modifications to the design due to the constraints of the injection moulding process.

Key findings

This project resulted in a fibreglass low flush system which performs well with either toilet paper or newspaper used as an anal cleansing material with a 2.5 litre flush. User acceptance of the system was good, with staff and learners at two schools making no distinction between low flush and standard toilets installed in the same blocks. A prototype adapted to meet the requirements of injection moulding was produced which performs well as a *pour flush* system with either toilet paper or newspaper at 1.5 litres and as a low flush system with toilet paper, but not newspaper, at 2.5 litres. The system performed variably, and in some cases poorly, with newspaper tested up to 4 litres, and further modifications are required to overcome this.

A low flush system addresses a number of needs as it achieves the following:

- it provides an onsite flush system which can be installed in many contexts, including rural or crowded communities where laying sewers is not a realistic option
- it introduces a sanitation option which is more progressive than standard waterborne sanitation in terms of stewardship of water resources
- it provides a competitively priced alternative to the VIP, allowing municipalities to move away from a “one size fits all” approach to sanitation delivery which can undermine agency and ownership
- it provides greater safety to young children than does a pit latrine
- it provides the convenience and safety of an indoor toilet if this is desired by the household
- it provides a greater sense of cleanliness than does a pit latrine by removing the sight and smell of faecal material away from the user.

In addition, pit latrines typically need to be emptied manually, both because of the dryness of the sludge and because of the presence of large amounts of rubbish. With the low flush system, the addition of a small amount of flush water results in a slightly wetter, more uniform material while a design that flushes material away rather than allowing it to drop through a pedestal to a pit discourages the disposal of rubbish into the pit. This results in a sludge which can which can be removed by a standard vacuum

tanker or removed to a small treatment plant or communal digestor via a small bore sewer, reducing the risks to workers' health or to the environment that exist with manual pit emptying. Alternatively, twin pits can be constructed and while the second pit is in use sludge in the first pit can be left to degrade and dewater, reducing in volume.

Interviews conducted with learners and school staff members in this study revealed an inadequate understanding of disease transmission and prevention, particularly with regard to helminths, which are prevalent in the Durban area. In addition, the practices of open defecation and soil eating were reported at some households which can undermine gains made in the protection of health through improved sanitation.

Conclusions

The prototypes produced in this study demonstrate that a low flush system can perform well where either toilet paper or newspaper are used for anal cleansing, although further modification is needed in order to maintain this level of performance with an injection-moulded model of the prototype.

Low flush technology has proven successful in this project in both institutional and domestic contexts on a small scale, providing a 40 to 70% savings of water over standard toilets which typically require between 4.5 litres and 9 litres to flush. It provides a sanitation model in which scarce water resources are used responsibly and sustainably, pointing a way forward not only for those who find dry sanitation unacceptable but also for standard sanitation design which in its current form is unsustainable as it relies on freely available water.

This technology may provide a viable option to municipalities under pressure to provide waterborne sanitation where laying sewers is not feasible or affordable. In addition, it could provide an option for householders desiring a flush toilet to upgrade their VIP systems to a low flush toilet on their own initiative. The low flush system can be installed indoors, reducing the costs of building a separate structure, or it can be installed in an existing VIP structure with the addition of a soak pit built beside the structure. It is essential that wherever low 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. As many households in South Africa are unable to afford toilet paper, the ability of the low flush system to accommodate newspaper makes this a technology which municipalities could specify even for poor communities and which poor families could opt for with a one-time expense of upgrading their system but without incurring the long-term expense for toilet paper which they may not be able to sustain.

Low flush technology shows the potential for overcoming one of the thorniest problems facing municipalities: the difficulty of removing sludge from pits. While VIP sludge is often too dry and contains too much rubbish to be removed with a vacuum tanker, the low flush system is far more conducive to vacuum removal because sludge contains less rubbish and has a higher moisture content.

Recommendations

At the time of the writing of this report, Envirosan, a plastics company in Durban, is in the process of producing an injection moulded low flush pedestal, which will bringing the cost of a pour flush unit down to the same range as that of a VIP pedestal. Further modification of the low flush design is required in order to

work within the constraints of the injection moulding process. Once this is achieved, low flush technology will be ready for piloting on a larger scale in both residential and institutional contexts.

With diarrhoeal diseases still a leading cause of death among young children and vulnerable people (WHO, 2013), and helminthic infections affecting as many as 80-90% of children in some South African studies (Appleton, Maurihungirire and Gouws, 1999; Appleton et al., 2008), it is imperative that an aggressive health and hygiene education programme be included in any sanitation intervention aimed at changing high risk behaviour.

ACKNOWLEDGEMENTS

The research team thanks eThekwini Municipality, Sizimesele Primary School, Thandaza High School and the two families which participated in the pilot study for their cooperation in making this study possible.

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1. INTRODUCTION

The need for basic sanitation

The fundamental purpose of providing sanitation is to prevent direct contact between people and their excreta via a "user interface" and safely remove or contain that excreta so that it doesn't contaminate their environment, putting them at risk of contracting various diseases which can compromise their health or even put their lives at risk.

While technologies in many fields have evolved to a very high level over the past century, the very basic issue of how to effectively and safely create that barrier between user and excreta has remained a perplexing question. The standard flush toilet that we use today has not evolved significantly since it replaced the chamber pot and outhouse in the late 1800s. And while in South Africa standard flush systems still dispense with 6 to 9 litres of clean water with every flush, is becoming obvious to an increasing number of people that it is nothing less than ludicrous to "shit in our drinking water."

In a country like South Africa, where a large percentage of the population live in rural areas and rely on the government for basic services, providing waterborne sanitation to every home is an impossibility. Instead, the standard for safe, basic sanitation has become the VIP (Ventilated Improved Pit) latrine – a big step forward over many home built pit latrines in terms of safety, hygiene and smell. VIPs meet the criteria for providing an adequate barrier between user and excreta, and approximately 1.9 million units have been built by the South African government since 1994 (Department of Water Affairs, 2013). The technology isn't without its problems though. On the social level, some individuals and communities have rejected it, viewing it as an inferior option to a flush toilet and therefore politically unacceptable in the post-apartheid context. As a result, while municipalities have typically tried to resolve the issue by providing waterborne sewerage in urban areas and dry on-site sanitation in rural areas (with no overt discrimination on the basis of race), some have been forced by the demands of their constituencies to provide waterborne sewerage more widely.

In the search for an alternative between the extremes of full waterborne sewerage and pit latrines, a few municipalities have experience with various low flush on-site systems which have been developed in South Africa. In a previous study for the Water Research Commission, users were interviewed in three communities using the DSA and Hungerford-Schroeder low flush systems (Still and Louton, 2012). Some of the issues that had emerged over time which caused dissatisfaction among users were that complicated components and moving parts could break over time causing system failure. Because these components were not standard and the technologies did not get standardised to the extent that parts could be sourced from local hardware shops, broken components could not be replaced. The lack of a proper water seal resulted in unpleasant smells. The use of newspaper for anal cleansing caused blockages in the systems. When cisterns broke users were forced to pour water to flush the toilets which did not work effectively.

Clearly, if some sort of intermediate option between dry sanitation and waterborne sanitation was possible, it needed to meet the following criteria:

- it had to be simple in design, without complex components which could block or moving parts which could break
- it must have an effective seal to keep smells and insects from coming up the toilet from the pit
- it must be robust enough to handle newspaper and
- it must use easily sourced parts.

Pourflush: an option for South Africa?

Of course, South Africa is not the only country faced with this problem. In India, the drive to eliminate dry sanitation arises from the government's commitment to end manual bucket and pit emptying. The alternative which has been implemented in India and other parts of Asia is a simple pour flush system, in which water poured by hand into the toilet pan pushes excreta through a water seal and into a pit.

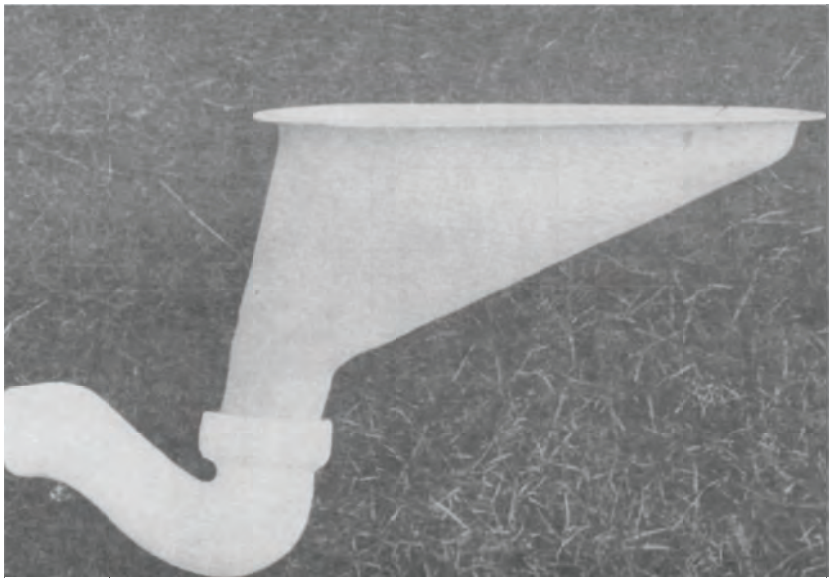


Figure 1.1 The "goose-neck" type of pour flush latrine first used in Thailand in 1924 (Mara, 1985)

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), with a squatting plate located directly over the pit. 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 NGO *Sulabh International* has built more than 1 million of these units to date. The key parameters of the Asian toilet are the 25° slope of the front of the pan, and the 75-70 mm diameter of the outlet pipe.

There were two major barriers to the India toilet making its way to South Africa: it used a squat plate, rather than a pedestal, and users used water, rather than toilet paper or newspaper, for anal cleansing. For these reasons it was not thought that the technology would be accepted or be robust enough to succeed in South Africa.

In 2009, Partners in Development was contracted by the Water Research Commission to develop a pour flush system appropriate to the South African context. The objective was to design a system which used the principles of the Asian toilet but looked much like the standard flush toilet aspired to by most dry system users and was moreover 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. Pour flush units were then installed at 23 sites which consisted of 22 homes which had previously had either VIP toilets or failed low flush systems, and a crèche. The units were monitored since their construction; at the time of writing the first units to be installed have been in operation for approximately 3 years. The only blockage that has been reported at any of the units was caused by a child flushing a plastic grocery bag into the toilet (to see what would happen). The success of this pilot study paved the way for a larger trial of pour flush technology.

Figure 1.2 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.

Why a low flush system?

In May 2011 eThekwini Metro Municipality asked Partners in Development to consider developing the pour flush system into a low flush system which could be used in public schools. eThekwini has increasingly taken over responsibility for sanitation in the rural public schools within the Metro, which number over 400. Some of the schools have VIP toilets, sometimes with a shared pit which has proven exceptionally difficult to empty. Others have standard flush waterborne systems which result in a high level of water usage by the school. The pour flush model could provide a solution to some of these issues but is not practical for an institutional context because pouring water must be made available at all times. If it runs out and the toilet is used repeatedly without being flushed, it is likely to block.

With support from the Water Research Commission, this project was designed with the following aims:

- to enhance dignity and a sense of equality among users who perceive their dry sanitation systems as inferior to flush systems.
- to design and test a robust low flush system to contribute to the development of a range of on-site sanitation options which take into consideration all aspects of the life cycle of a system, including user behaviour, pit emptying and beneficial disposal of sludge.
- to impact the knowledge, attitudes and behaviours of toilet users to reduce disease transmission.
- to promote conservation of water resources and the uptake of sanitation options which use less water than standard waterborne systems.

2. PROTOTYPE DEVELOPMENT

The development of a low flush prototype focused on modifying the pour flush design that had proved successful in the earlier project, *Piloting and testing the pour flush latrine technology* (Still & Louton, 2012). Externally, the fibreglass 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. Specifications for the pour flush / low flush pedestal and sewer can be found in Appendix A.

Figure 2.1 Pour flush pedestal and outlet

The primary modification that was required was to add a cistern, so that a flush would be dispensed by a handle action rather than dumping water from a bucket into the bowl. However, during the development of the pour flush toilet it had been found that the effectiveness of the flush depended largely on the way in which water was poured into the toilet, rather than on the volume of water. In particular, it was found that a strong "dumping" action often allowed effective flushing with only one litre of water. A second observation was that the pour flush unit worked particularly well because of the steep exit of the toilet. Development of the low flush prototype began, then, with the possibility that other modifications might be necessary in order for a flush dispensed by a cistern to be successful.

2.1 Cisterns

Four commercially available cisterns were tested during the development of the low flush prototype. Where possible, the cisterns were modified to deliver only a two litre flush. No discernible difference was found in performance. A stand-empty low flush cistern (4.5-6 litres) by Gidamathathu Environmental Solutions was initially selected. This cistern is designed, patented and manufactured in South Africa and is relatively low cost. It had the added advantage of standing empty between flushes, reducing the loss of water through leaking seals. While this cistern is designed to deliver a flushing

volume in the range 4.5 to 6 ℓ, for the purposes of this research it was modified to deliver either 1, 1.5, 2, 2.5 or 3 ℓ at a time. The disadvantage of the stand-alone design, however, was that there was a lag time while the cistern filled after operating the flush handle. For this reason it did not seem ideal for a school environment. A Parker, CUB 1 ℓ flush cistern manufactured by Calcamite cistern was also tested but was abandoned when testing proved that a single litre was inadequate for flushing newspaper. The Elf PBX 011 9 ℓ cistern manufactured by Dutton Plastics Engineering proved successful for testing. When the prototype was ready for installation at schools, however, it was decided to use the same cistern that would be used for the standard toilets so that the low flush units would be visually as similar as possible to the other units. This was a Gemini 6 ℓ cistern, manufactured by Atlas Plastics.

To achieve a 2.5 litre flush, a longer flushing arm was used which was manually bent down to the required level and the flush amount was measured using a meter until the toilet flushed at 2.5 litres on average over 10 flushes.

Figure 2.2 A longer arm was needed for the Atlas cistern so that it could be bent down to limit the flush to 2.5 ℓ

2.2 Pedestal and pan

Leaving the base and exit pipe of the pour flush prototype unchanged, a "flushing ring" was added to the top of the pan. This was a hollow section which overhung the sides of the pan. Into this overhang a slot was cut at the front of the toilet and seven holes were drilled around the back and three on each of the sides.

The "flushing ring" was fitted with a water entry point (on a standard 2 inch pipe) at the back of the toilet. It was found upon testing that the design yielded very good results with a strong jet of water directed towards the toilet exit (emulating the dumping action) and with a smaller amount of water being released around the rest of the pan for lubrication and cleaning.

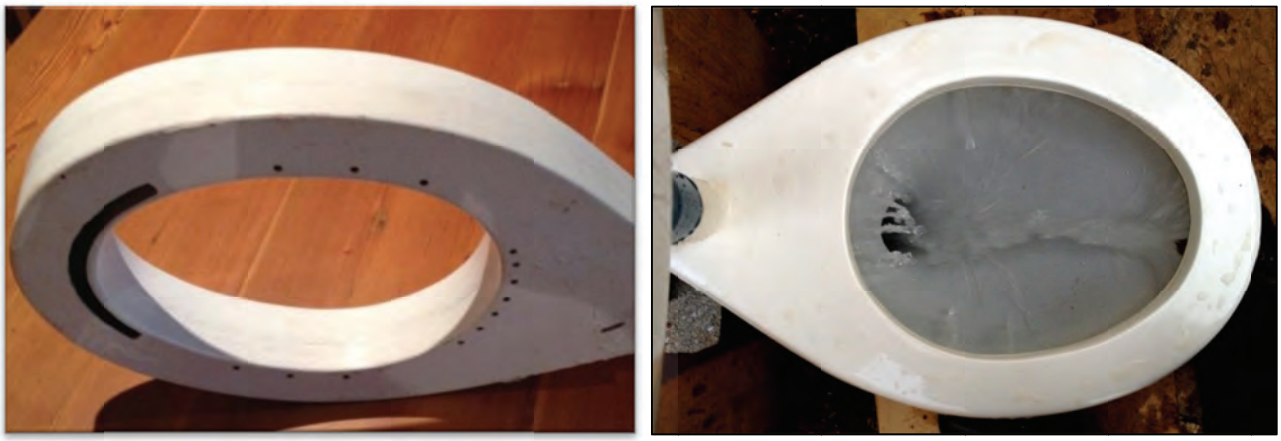


Figure 2.3 "Flushing ring" with slot and holes (left) and flush action (right) showing a strong jet of water directed towards the outlet

2.2.1 Testing the first prototype

Test rig

A test rig was constructed which allowed the cistern to be moved to various heights relative to the pan to test the impact of cistern height on the flushing action. The cistern was plumbed in 300, 600 and 900 mm above the pan. The toilet outlet passed through a water trap and into a standard outlet pipe sloped at 2% towards a bucket which could collect simulated faecal samples and toilet paper during testing.

Figure 2.4 Test rig

Testing protocol

For the purposes of testing, the same protocol was used as in the development of the pour flush unit – 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 simulated faecal matter plus toilet paper in a single flush, without plugging or clogging on 4 out of 5 attempts in order to pass. Simulated faecal samples made of 50 g of soy paste contained in a latex sheath were used. The prototype was tested using 6x50 g samples, comprising a simulated faecal load of 300 g.

Since newspaper is frequently used in South Africa for anal cleansing, testing was conducted with both toilet paper and newspaper: 4x5 squares of toilet paper were used and 4x¼ sheets of newspaper were used. It became clear that the way in which newspaper was folded was an important factor: when it was folded up it had a higher tendency to block the toilet, but when it was scrunched up it presented less difficulty.

The samples were flushed at the three cistern levels and in each case a variety of flush volumes was tested, starting at 1 ℓ and finishing at 3 ℓ in 500 mℓ increments. The number of samples passed in the first flush was recorded. The results are provided in Appendix B. With 5 flushes for each volume at each height, it was found that all 6 of the samples flushed at the median from a volume of 2 litres for a flush and upward for toilet paper and 2.5 litres and upward for newspaper.

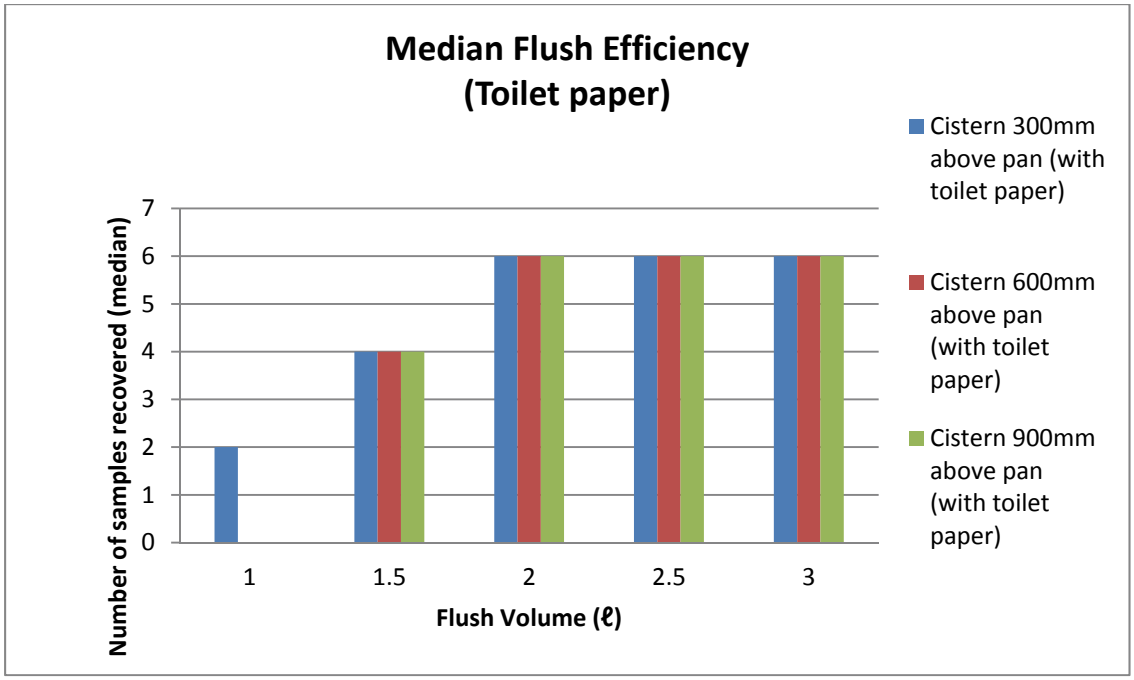


Figure 2.5 Flush efficiency during testing of first prototype for toilet paper

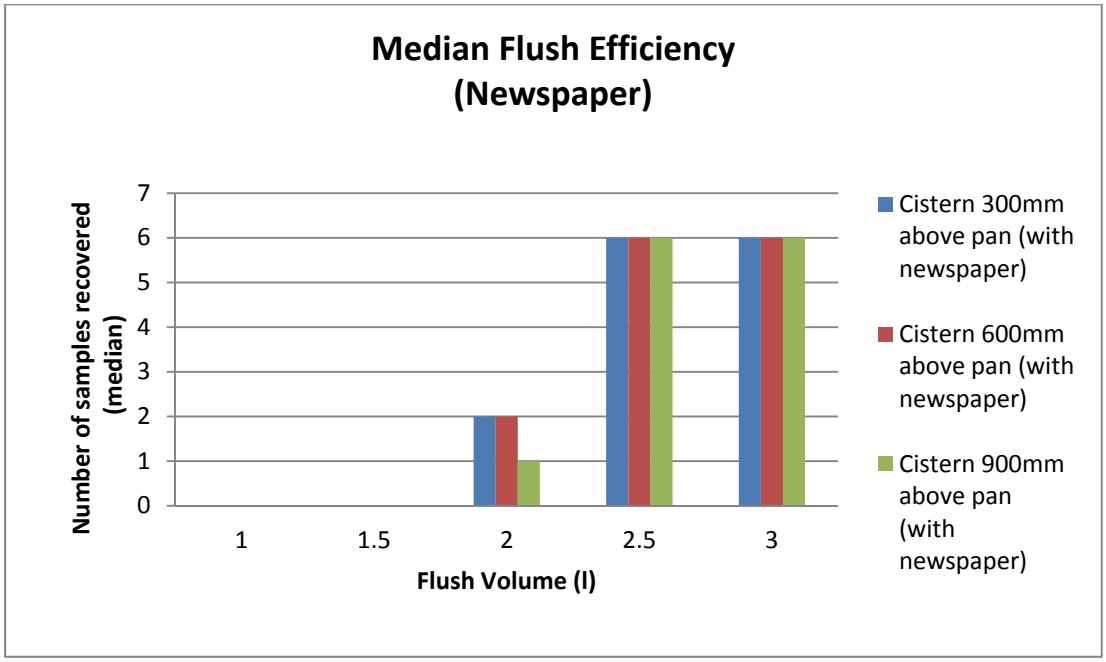


Figure 2.6 Flush efficiency during testing of first prototype for newspaper

The flush height therefore did not have an observable impact on the effectiveness of the flushing. The use of newspaper clearly removed energy from the water stream, requiring typically an additional 500 mℓ of water for adequate flushing.

The first low flush prototype therefore proved successful, performing consistently on 2 ℓ of water.

2.2.2 Second prototype

A second prototype was designed with the objective of introducing the water from the back of the cistern on a gradual bend to reduce friction losses. However, an unintended consequence of this change was that the rim flush ring became much thicker, which negatively affected the performance of the device.

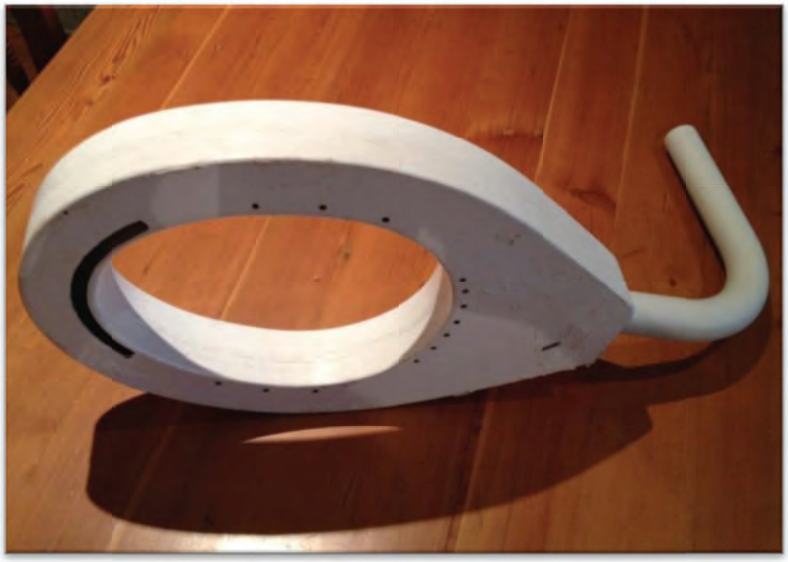


Figure 2.7 Gradual bend of pipe on second prototype. The introduction of the flush water from the back resulted in the thickness of the rim being significantly increased, which negatively affected performance.

Testing

The results of the test with the second prototype proved far less consistent than those for the first prototype. As the cistern was lifted higher the performance of the toilet actually diminished. This was attributed to the loss of pressure in the thicker rim flush ring.

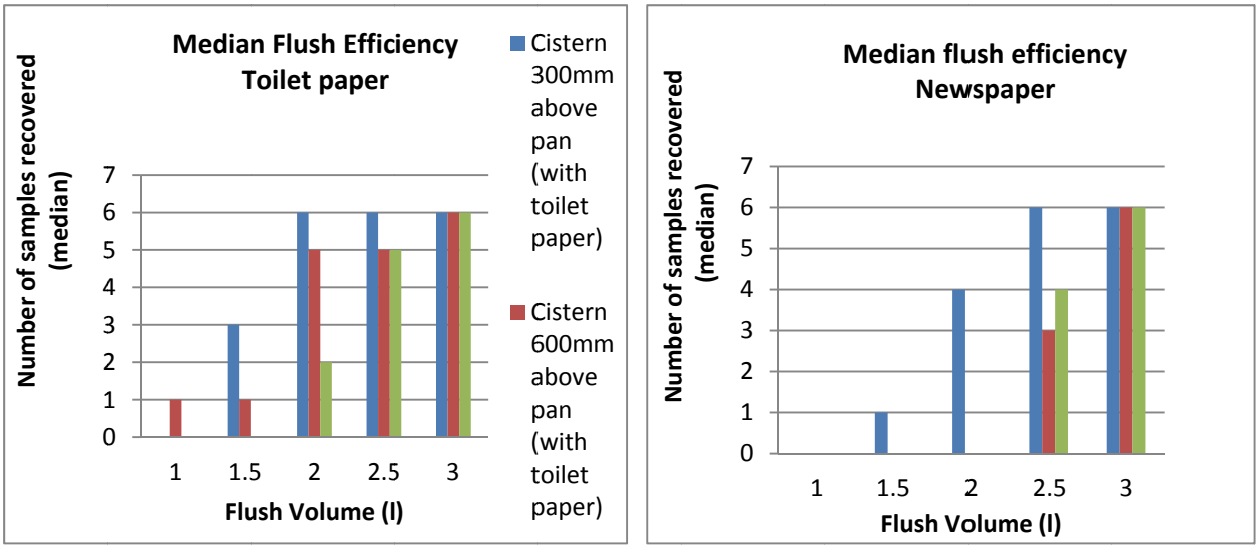


Figure 2.8 Flush efficiency during testing of second prototype for toilet paper (left) and newspaper (right)

2.3 Selection of prototype for pilot study

The first prototype was retained for the pilot due to the excellent results achieved in testing. It was thought that the thinness of the flushing ring resulted in the quick build-up of positive pressure which was then transferred to the water at the outlet as a result of head in the cistern.

For the pilot in schools, the Atlas Plastics cistern was selected. This was to achieve as much consistency as possible with the standard toilets installed alongside the trial units.

2.4 Development of prototype for injection moulding

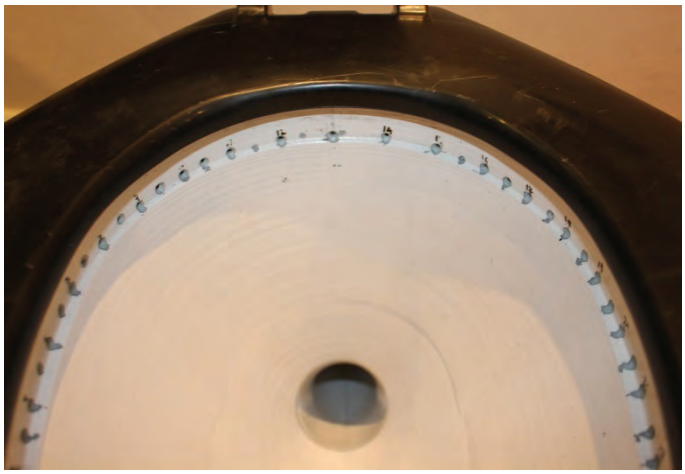
Envirosan, a plastics company in Durban, was approached to see if they would be interested in manufacturing injection moulded low flush units. The company expressed a willingness to explore the idea and invest in the injection moulding process if there was evidence of a great enough demand to be able to recover the development costs relatively quickly. In July, 2013 a 3 dimensional pan was printed using a 3D printer which could be inserted into a standard Envirosan pedestal and fitted with a standard Envirosan toilet seat.

Figure 2.9 Prototype pan and gooseneck outlet

Figure 2.10 Standard Envirosan pedestal (left) with low flush pan and rim flush ring inserted (right)

In order to accommodate the moulding process, some design modifications were required. The inlet for flush water had to enter the flushing ring through a U bend, which resulted in some loss of energy. In addition, the flushing ring could not be mounted in the same way. The flush was dispensed through a main cutaway at the front of the pedestal, and holes were drilled into the rim for the dispensing of water for the general flush. It was unknown what impact this would have on the cleaning action of the flush, as water would not wash directly down onto the pan but first shoot out from the side.

Figure 2.11 U shaped pipe providing inlet to flushing water



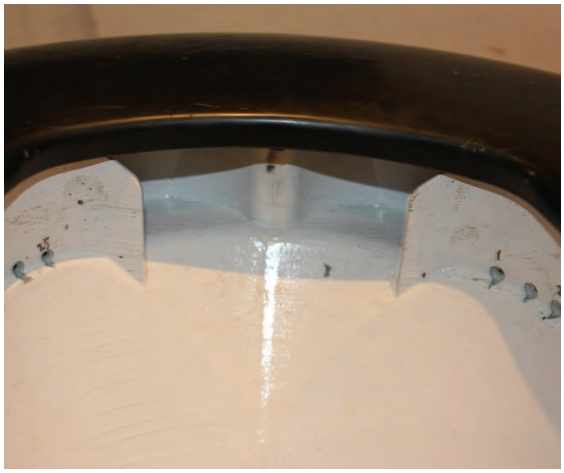


Figure 2.12 Flushing ring with 43 holes drilled along the water channel to rinse the pan (left) and section cutaway at front to provide a forceful flush (right)

Tests were done on the unit as designed and then additional modifications were made and it was tested again. A foam strip was inserted into the flushing ring to reduce the volume and increase the force of the flushing water. In addition, 25 holes were drilled around the rim of the pedestal to dispense flushing water. Holes were then drilled between these holes, for a total of 43 holes, to allow different combinations of holes to be blocked to test the cleaning action

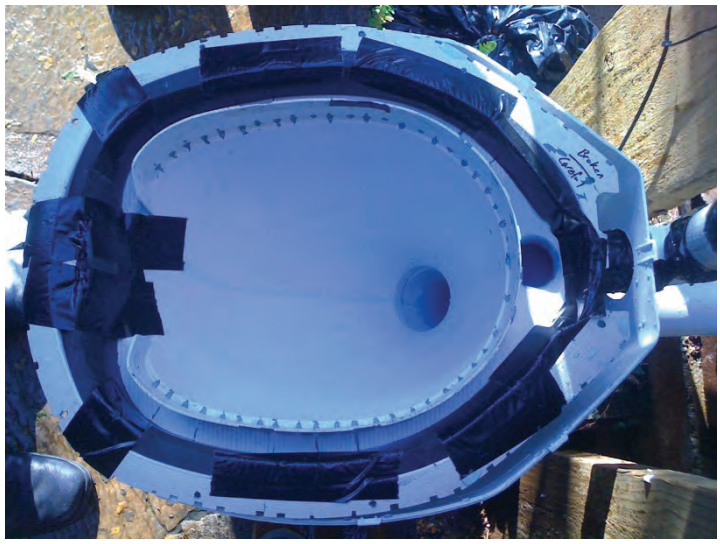


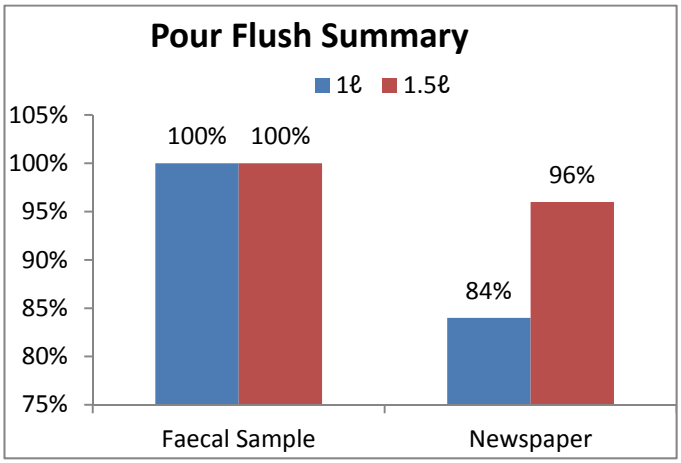
Figure 2.13 Strip of foam taped into the water channel to reduce volume

The unmodified Envirosan prototype was tested on 16 July 2013. Tests were conducted using 5 simulated feacal samples and 5 quarter sheets of newspaper which were rubbed against each other to soften them and then crumpled as is commonly done when newspaper is used for anal cleansing. Five tests (flushes) were conducted for each of a range of volumes.

Pour flush tests

A pour flush test (pouring water directly into the pan rather than using the cistern) was done using volumes of 1 and 1.5 litres. It was found that all faecal samples passed through the system into the collection container at both 1 and 1.5 litres, while 84% of the newspaper arrived at the collection container with a 1 litre flush and 96% of the newspaper arrived at the collection container with a 1.5 litre flush. It was found in observations during the pour flush pilot study that as long as the faecal matter, toilet paper or newspaper cleared the gooseneck it did not need to (and probably wouldn't) reach the pit on the same flush, but would rather get pushed along the sewer on subsequent flushes until it reached the pit without causing blockages. Tests therefore confirmed reports from pour flush users that the system could be used successfully as a low flush unit using 1 to 2 litres of water even if newspaper was used for anal cleansing. Detailed results of the low flush tests can be found in Appendix B. A summary of the results for the low flush tests is presented in Table 2.1.

Table 2.1 Summary of pour flush tests for different volumes with unmodified Envirosan prototype

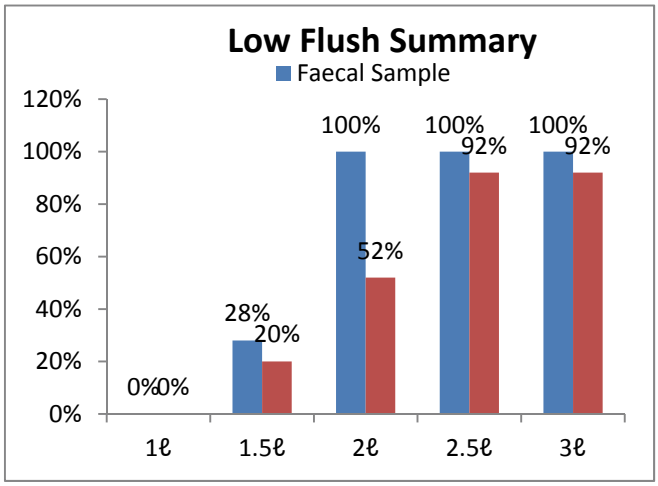


Pour Flush Summary		
ℓ	Faecal Sample	Newspaper
1	100%	84%
1.5	100%	96%

Low flush tests

Low flush tests were done with the cistern filled at 1, 1.5, 2, 2.5 and 3 litres. None of the faecal samples or newspaper sections passed into the collection container with a 1 litre flush; roughly a quarter did with a 1.5 litre flush. At 2, 2.5 and 3 litres all of the faecal samples passed while at 2 litres 52% of the newspaper sections passed and at both 2.5 and 3 litres 92% of the newspaper sections passed. This indicated that without modification the Envirosan prototype performed adequately with a 2.5 litre flush, as did the previous prototype which was installed in schools and homes for this study. Detailed results of the low flush tests can be found in Appendix B. A summary of the results for the low flush tests is presented in Table 2.2.

Table 2.2 Summary of low flush tests on unmodified Envirosan prototype



Low Flush Summary		
	Faecal Sample	Newspaper
1	0%	0%
1.5	28%	20%
2	100%	52%
2.5	100%	92%
3	100%	92%

Further testing

On 24 July, 2013, further tests were conducted using the Envirosan prototype. Four variations, each with five repetitions, were tested using toilet paper and again using newspaper. The four variations were as follows:

Test 1: No changes to prototype
Test 2: 25x3 m diameter holes added to rim
Test 3: 25x3 m diameter holes added to rim, with foam strip inserted to reduce rim volume
Test 4: 43x3 mm diameter holes added to rim, with foam strip inserted to reduce rim volume

Figure 2.14 Testing the 3rd prototype

For each test, 5 faecal samples (soy paste in latex sheath) were used as well as either 3x10 sheets single ply toilet paper folded 3 times or 3x1/4 sheet newspaper folded once, softened (by rubbing) and crumpled.

Detailed results for the tests can be found in Appendix B. A summary of results is found below in Tables 2.3 and 2.4.

Using toilet paper it was found that the toilet performed well at 2.5 litres for Tests 1, 2 and 3 but only at 3 litres for Test 4. Performance was highest for Test 2, with all samples passing at 2.5 litres and all faecal samples passing at 2 litres with 67% of toilet paper passing for Test 3 and 80% for Test 2.

Table 2.3 Testing results for 3rd prototype using toilet paper

Results of 4 tests using toilet paper								
	Test 1		Test 2		Test 3		Test 4	
Litres	Toilet paper	Faecal sample	Toilet paper	Faecal sample	Toilet paper	Faecal sample	Toilet paper	Faecal sample
2	47%	96%	80%	100%	67%	100%	60%	100%
2.5	93%	100%	100%	100%	100%	100%	67%	100%
3					100%	100%	100%	100%
3.5					100%	100%	100%	100%
4								

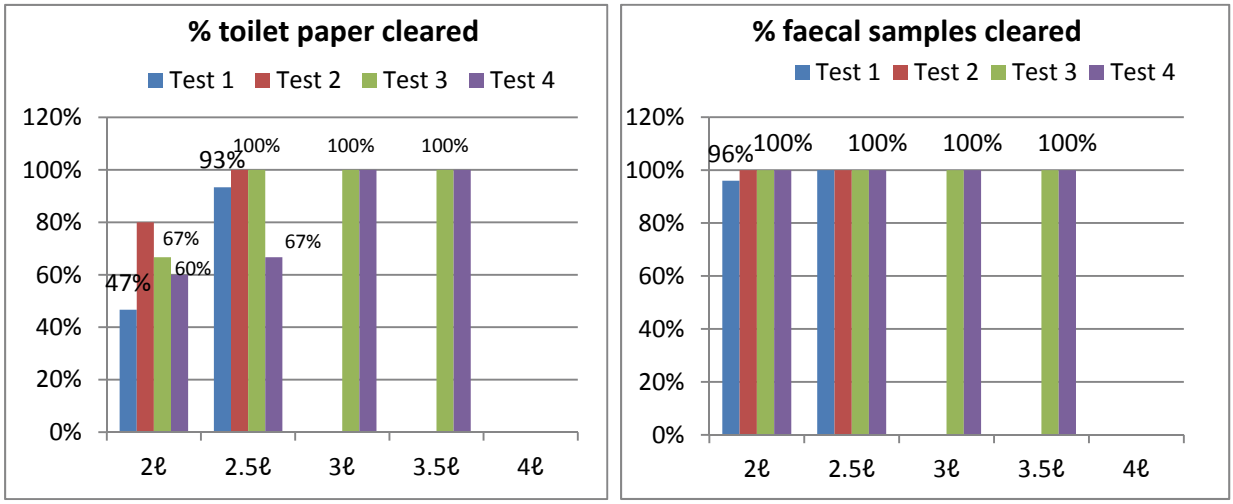


Figure 2.15 Percentage toilet paper (left) and faecal samples (right) cleared on tests with third prototype

With newspaper, it was found that the faecal samples passed through the system relatively well with a 2 litre flush or greater (100% for all tests except Test 1), but newspaper did not pass through easily even with higher volume flushes.

Table 2.4 Testing results for 3rd prototype using newspaper

Results of 4 tests using toilet paper								
	Test 1		Test 2		Test 3		Test 4	
Litres	News paper	Faecal sample	News paper	Faecal sample	News paper	Faecal sample	News paper	Faecal sample
2	0%	84%	0%	100%	7%	100%	7%	100%
2.5	0%	96%	7%	100%	7%	100%	13%	100%
3	7%	100%			53%	100%	27%	100%
3.5	40%	100%			80%	100%	73%	100%
4	87%			80%		100%	93%	100%

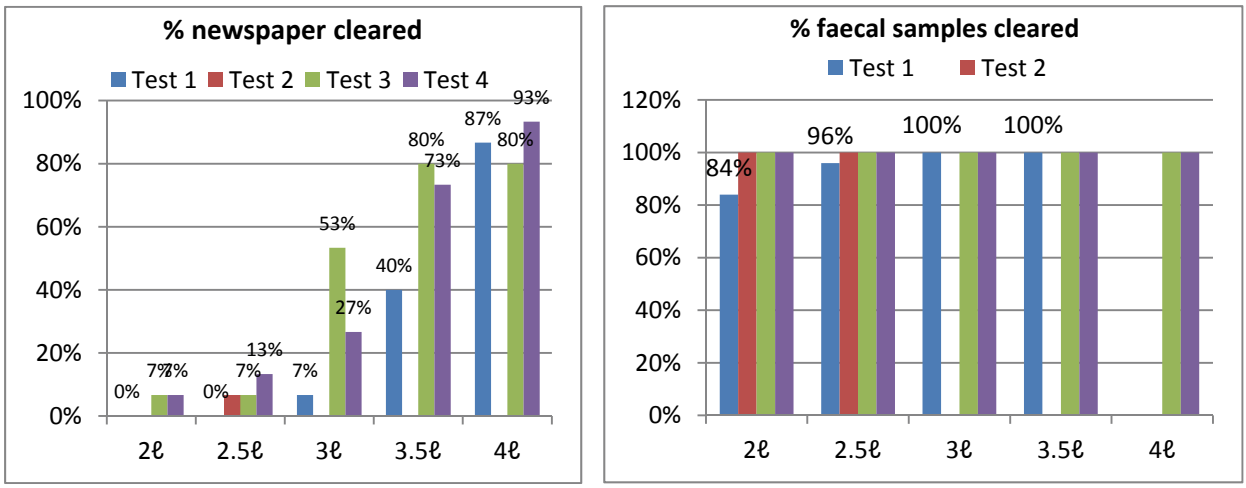


Figure 2.17 Percentage newspaper (left) and faecal samples (right) cleared on tests with third prototype

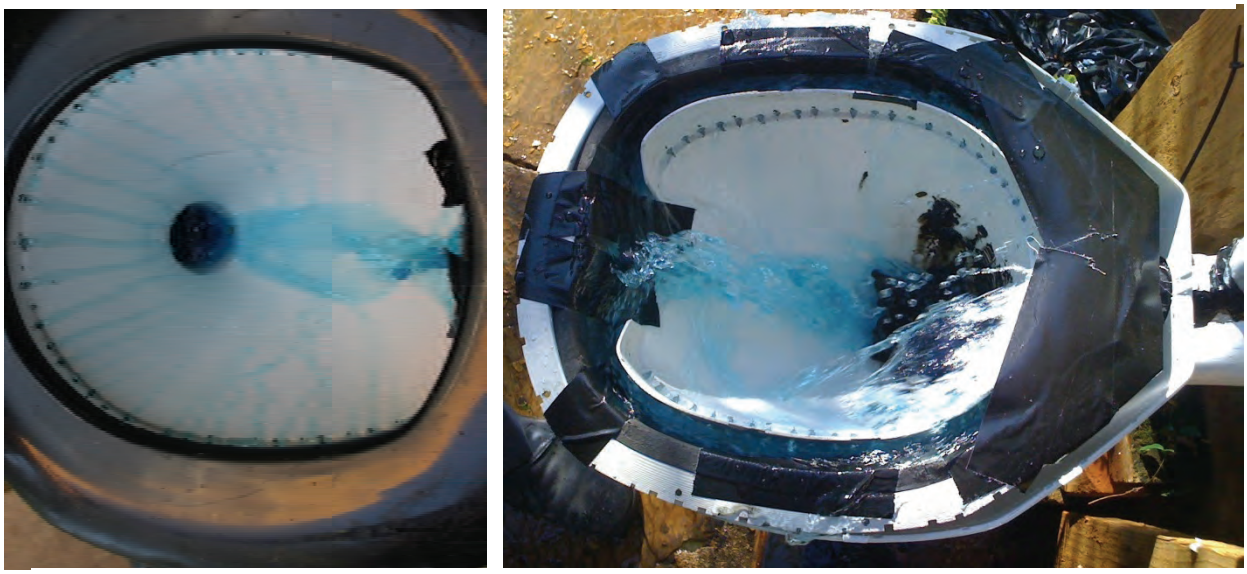


Figure 2.16 Testing the performance of the prototype with 43 holes for rinse water (left) and while flushing pig slurry (right)

3. SITE SELECTION

3.1 Schools

In consultation with eThekwini Water and Sanitation (EWS) two schools were selected to participate in the trial. Sizimesele Primary School is located in rural Molweni in the Waterfall/Hillcrest area and Thandaza High School is located between Hammarsdale and Mpumalanga. It was proposed that three toilets be placed in each school: one in the boys' block and one in the girls' block.

3.1.1 Sizimesele Primary School, Molweni

Sizimesele Primary School was built in 1978. Enrollment in July 2013 was at 239, with 125 boys and 114 girls. Of the ten staff at the school, 7 were women and three men. Information was obtained from a Head of Department on 15 July, 2013 as the principal was on leave due to health issues. The school was originally built with VIP pit latrines. By 2012 these had become smelly and unhealthy, according to the HOD, who described seeing small animals and flies in the toilets. Because the toilets were not locked their use and condition could not be monitored outside of school hours, and they were sometimes used by people from the surrounding area, who also at times helped themselves to the toilet paper provided in the loos. In 2012 when construction was to begin on the new toilets the pit latrines were demolished. Portable chemical toilets were provided to the school until the new toilets were completed.

Figure 3.1 Sizimisele Primary School located in rural Molweni, KwaZulu-Natal, South Africa

Figure 3.2 Sizimesele Primary School

3.1.2 Thandaza High School, Hammarsdale

Information about the school was obtained from the principal during an interview on 17 April 2012.[1] At present 886 learners are enrolled at the school which is served by a staff of 37, 29 of whom are women (68%) and 12 of whom are men (32%).

The school was provided with VIP toilets in 1998. These were later replaced by a small number of flush toilets. In April 2013, the 3 girls' toilets were serving 522 girls (a user ratio of 1:174, and the boys toilets (2 pedestals plus a wall urinal) were serving 364 boys (a facility:user ratio of 1:73).

Figure 3.3 Thandaza High School in the rural Hammarsdale area

The principal indicated that the main issue around the old toilets was that the number of toilets was inadequate. Besides overcrowding, which forced learners to queue at break time, this resulted in blockages and a very unpleasant smell due to the volume of material handled. There were also problems with vandalism, primarily on the part of the boys; also metal water taps and other steel fittings were taken.

Figure 3.4 Thandaza High School

Historically the toilets were cleaned by the learners, but more recently a cleaner had been hired who cleaned the toilets daily. Maintenance issues such as a leaking pipe or blocked toilet were to be reported to the Department of Works. In the past, the Department of Works had had a local office and would come to attend to the problem the same day it was reported; however the local office had now

[1] The interview questionnaire can be found in Appendix D.

closed and the new protocol was to contact the Department of Education. The principal reported that there was so much red tape that problems reported did not get addressed. They therefore used their own funding to hire a plumber directly. Rubbish was collected weekly but papers were burned.

3.2 Private homes

In addition to the school installations, two homes in the Azalea area of Msunduzi Municipality were converted to low flush systems. These homes had been part of the pour flush trials since September 2010 and January 2011, and their systems had by this stage performed well for 30 and 26 months respectively.

Figure 3.5 Pour flush toilets selected for conversion to low flush systems

4. CONSTRUCTION

4.1 Sizimesele Primary School

At Sizimesele Primary School, a girls' toilet block was constructed with 6 toilets and 4 sinks. This provided 1 toilet per 19 girls and 1 sink per 28 girls. Two of the systems installed were low flush toilets. The boys' block contained 2 toilets, one of which was a low flush, 2 urinals and 2 sinks, providing 1 toilet per 31 boys and 1 sink per 62 boys. Staff toilets were also built but did not include any low flush toilets.

Figure 4.1 Newly built toilet blocks at Sizimesele Primary School

Table 4.1 Numbers and ratios of users and toilets at Sizimesele Primary School

Users	Number of users	Number of toilets	Toilet to user ratio	Number of sinks	Sink to user ratio
Girls	114	6	1:19	4	1:28
Boys	125	4	1:31	2	1:62
Female staff	7	2	1:3	2	1:3
Male staff	3	2	1:2	1	1:3

The Department of Education was scheduled to open the new toilet blocks at Sizimesele Primary School on 9 April, 2013, but due to unrest in the area related to teacher strikes, the handover of the toilets to the school was postponed. Eventually the contractor was given permission to hand over keys to the school and they were opened for users on 15 May.

Figure 4.2 Stalls (left) and a pour flush unit (right) in the girls' toilet block at Sizimesele Primary School

4.2 Thandaza High School

A toilet block constructed with two buildings separated by a Jojo tank was built at Thandaza High School. The toilet blocks were attractive, painted in blue and cream with fibreglass panels in the ceiling allowing natural lighting into the blocks. The atmosphere inside the blocks was light, spacious and pleasant. The toilets drained to a 4 m wide x 5.4 m long x 2.8 m deep septic tank and 2 50 m^2 soak aways. The size of the soak aways was determined by a percolation test prior to construction.

Figure 4.3 Toilet blocks at Thandaza High School

Figure 4.4 Stalls in the girls' toilets (left) and sinks in the women's staff toilet (right)

The girls' block was fitted with 11 toilets, the first two of which were low flush units, and 6 sinks. With 522 girls enrolled, this gave a toilet:user ratio of 1:47.[2] The boys' block was fitted with 3 toilets, the first of which was a low flush unit, 4 urinals and 2 sinks. For boys, the ratio was even higher, with 1 toilet to 52 learners. The female staff toilet block contained 4 toilets and 2 sinks and the male block one toilet, a urinal and a sink. There was a separate toilet for the handicapped. The ratios for toilets and sinks to users is summarised in Table 4.2 below.

Table 4.2 Toilets and sinks per user built at Thandaza High School

Users	Number of users	Number of toilets	Toilet to user ratio	Number of sinks	Sink to user ratio
Girls	522	11	1:47	6	1:87
Boys	364	7	1:52	2	1:182
Female staff	25	4	1:6	2	1:12
Male staff	12	2	1:6	1	1:12

The Department of Education opened the new toilet blocks at Thandaza High School on 10 April, 2013.

[222] The standard recommended by the World Health Organisation for school toilets is a toilet:user ratio of 1:25 for girls and 1:50 toilets and 1:50 urinals for boys (WHO, 2009)

4.3 Private homes

The pour flush toilets were converted to low flush in March 2013.

Figure 4.5 Pour flush toilets converted to low flush systems at homes in Azalea, Edendale

5. MONITORING

5.1 Schools

The actual testing phase of the project was delayed significantly due to delays in construction. When construction was completed at the end of March, monitoring visits were planned weekly for April, bi-weekly in May and once in June. Monitoring visits covered the following:

- Checking in with principal or HOD on the functioning of the toilets. As they did not distinguish between the low flush and standard toilets, we were given their comments about the toilets in general. We forwarded information about problems related to construction on to eThekwini Water Services.
- Installing water meters and logging meter readings
- Documenting the condition and functioning of the toilets and toilet blocks and any problems that arose.

For the low flush units the cisterns were adjusted to flush as close to 2.5 litres as possible, averaging the flush volume over several flushes.

5.1.1 Sizimesele Primary School

The toilets have been in use since 15 May.

On 20 May a monitoring visit was conducted. The toilet blocks were found to be clean and tidy, with toilet paper provided in all stalls. The low flush units were working well; however some of the water meters were not working for unknown reasons. In addition, the principal reported that 3 of the standard toilets were leaking. The leaks were reported to eThekwini Water Services. Another monitoring visit was conducted on 27 May. On 10 June the toilet leaks had been fixed. On 15 July, after the school holidays, the final monitoring visit was completed. There was some soiling in the toilet blocks but in general they appeared well cared for and all units appeared to be working well. One of the school's Heads of Department was interviewed and was asked if the staff or learners had noticed anything different about the low flush units. She said they were not aware of any difference between any of the toilets.

5.1.2 Thandaza High School

On a visit to Thandaza on 8 April it was reported that the staff toilets were already in use and that the learner toilets were scheduled to be commissioned on April 10. The school was visited again on 17 April. The principal indicated that there had been no problems with the toilets themselves within the first few days. However, the locked toilet roll holders had been stocked when the learner toilets were opened, but within the first hour of use all of the toilet rolls on every one of the 14 dispensers had been completely emptied, although the cardboard rolls themselves remained. As a result of this the principal decided to have toilet paper dispensed by a staff person to each learner for each use, and toilet paper

was no longer provided in the stalls. Due to this type of behaviour the principal felt that it was not feasible to try to provide soap to the learners, although she stressed the importance of it. It was suggested that perhaps a sink could be installed with a soap dispenser on the wall of the administration block, so that learners who wished to wash their hands with soap could do so but with the idea that doing it in the open in full view of staff would prevent abuse. Visits were made on 22 and 24 April during which faulty meters were replaced. On 29 April the principal reported a number of cases of vandalism on the toilet blocks; one water meter was leaking and it appeared that there had been an attempt to remove it. On 10 May meters were again repaired and replaced. Graffiti was noted on the walls of the toilet blocks. On 25 May and 10 June the school was visited again. The principal had noted leaking pipes at the back of the building and had had these repaired. While a cleaner cleaned the blocks daily they had already begun to look far more soiled than the blocks at the Sizimesele primary school. The final monitoring visit was made to the schools on 15 July with eThewkini Water Services and Aurecon, the managing consultant. All low flush units were performing well. A handle on one of the doors in the boys' toilet block had been broken off. Maintenance of the learner toilet blocks was clearly going to be a challenge due to user behaviour.

The principal indicated that she was satisfied with the units and had observed no difference with the low flush units. No blockages or other problems had occurred over the monitoring period.

5.1.3 Water consumption

Water meters were installed on all 8 toilets at Sizimesele Primary School and on the 3 boys' toilets and the first 4 of the 11 girls' toilets at Thandaza High School. It proved impossible to place a meter on the supply line as the block had been plumbed to bring water in from both directions on the line in order to raise the water pressure. On the low flush toilets, the flushing arm was bent to limit the flush to as close to 2.5 ℓ as possible. A mean volume per flush was calculated for each metered toilet. Water consumption was recorded on all visits to the schools. Unfortunately a number of the meters stopped working for unknown reasons, and ultimately data was collected from 5 of the 15 meters. The data that was collected from the working meters is presented in Table 5.1. Flush volumes for the low flush units ranged between 2.35 ℓ and 2.8 ℓ and for the standard units between 4.1 ℓ and 4.5 ℓ.

Table 5.1 Water consumption for low flush and standard toilets at both schools

Low flush unit*: Avg flush volume (ℓ)	Consumption/ week	Flushes/ week	Standard unit: Avg flush volume (ℓ)	Consumption/ week	Flushes/ week
SB1: 2.8	405	144	SB2: 4.35	369	85
SG2: 2.5	224	90			
TB1: 2.35	223	95	TB2: 4.1	3336	814
TG1: 2.5	3584	1433	TG3: 4.5	2417	537
TG2: 2.4	4229	1762			
Average	1733	705		2041	479

*S – Sizimesele, T – Thandaza, G – Girls' toilet block, B – Boys' toilet block

As the standard toilets used at these schools, with a flush volume of 4- 4.5 ℓ, already had a significantly smaller flush than that of most standard toilets, the water savings achieved by the pour flush toilet were

not as dramatic as they would have been for a typical standard toilet. What can be noted from the data above is that in most cases (although not all) the pour flush toilets were used more frequently than the standard toilets. The low flush toilets represented above also happened to be among the first toilets in the toilet block, and it is likely that in the case of a large toilet block – such as the girls' block at Thandaza High School which has 11 units – the units further down the row would have had even less usage. As a result, consumption of water per toilet was higher for the pour flushes in some cases than for the standard toilets which were used less. However, if data was obtained for the same toilets each having used 1000 flushes per week, they would compare as follows:

Table 5.2 Estimate of water consumption per unit for 1000 flushes per week

Low flush unit*: Avg flush volume (ℓ)	Consumption / week	Flushes/ week	Standard unit: Avg flush volume (ℓ)	Consumption/ week	Flushes/ week
SB1: 2.8	2800	1000	SB2: 4.35	4350	1000
SG2: 2.5	2500	1000			
TB1: 2.35	2350	1000	TB2: 4.1	4100	1000
TG1: 2.5	2500	1000	TG3: 4.5	4500	1000
TG2: 2.4	2400	1000			
Average	2510	1000		4316	1000

The lowflush toilet set at a 2.5 ℓ flush would achieve a 41% savings of water over the relatively low flushing standard toilet used in this study.

5.1.4 Issues arising during monitoring

No issues arose with the low flush units specifically during monitoring. A number of issues arose around the construction of the toilet blocks. These were reported to eThekwini Water and Sanitation and to the contractors who then followed up.

- Construction around door frames began to disintegrate. The contractor believed this was due to learners slamming the stall doors; however this problem was observed soon after construction was completed.
- Paint began to come off of the floors very soon after construction. The contractor said this was due to the sandy soil in the school environment, which operated like sandpaper.
- Urinals were installed without flushers. The consultant said that the flusher was left off in order to keep the urinals "waterless" – rather than users flushing the urinals, cleaning staff should pour water into the urinals daily.

Figure 5.1 Cracking door frames and urinals without flushers reported to eThekwini

- Some of the standard toilets began to leak. The contractor repaired these with silicone.

Other issues arose around user behavior:

- All of the toilet paper provided at Thandaza was stolen immediately on the first day that the blocks were opened, with the result that the school decided to have a staff member dispense toilet paper individually to students per use. This problem did not arise at Sizimesele Primary School.
- Graffiti was quick to appear in the toilets at Thandaza.
- A number of components were vandalized at Thandaza. The tap handle on the Jojo tank was broken off; there was an attempt to break off taps at the utility sinks installed at the rear of the toilet blocks; and caps were removed' also burn marks were evident around fixtures. Plastic taps and handles were installed at the toilet blocks as these are not considered a target for theft. Some of these were damaged with deep scratches, however, raising a hygiene concern as the grooves on the taps would harbor bacteria and be difficult to clean.
- Cigarettes were discarded in urinals.

The principal reported that drugs are a problem at the school and she attributes poor care of the toilets to students being under the influence of drugs.

Figure 5.2 Vandalism at Thandaza High School: An attempt to pull a tap out of a wall (far left), burn marks on the wall (centre left), missing caps (center right) and the tap for the Jojo tank broken off (far right)

5.2 Private homes

On monitoring visits on 7 May and 25 July, the householders reported that they had had no problems with their low flush toilets. Toilets at both households in the study appeared clean and well cared for.

6. USER EDUCATION

The fundamental purpose of providing sanitation is to break the cycle of faecal-oral disease transmission which compromises health. The provision of a toilet does not necessarily break this cycle on its own, however. Studies conducted by the Pollution Research Group at the University of KwaZulu-Natal have found evidence of intestinal parasites in the contents of nearly every domestic pit sampled, indicating that infections are widespread (Buckley et al., 2008). Attitudes and beliefs about parasites have been noted which indicate inadequate understanding of infection and routes of transmission (for example, the idea that infants are born with worms already in their gut). Parasites, viruses and bacteria transmitted from faeces can result in illnesses which can be life-threatening to young children, the elderly, and those whose immune systems are compromised by other infections such as HIV or TB. Periodic deworming accompanied by regular hand washing with soap after use of the toilet could dramatically reduce infection rates. The provision of new toilet blocks at schools created an opportunity to educate teachers and learners about the transmission of disease, how it can be prevented through deworming and a change in personal habits, and, ideally, influence and motivate users to make a shift to new behaviours at the same time that they make a shift to a new sanitation system.

Figure 6.1 Heath hygiene and toilet use education at Thandaza High School (left) and Sizimesele Primary School (right)

Presentations were made at Thandaza High School on 29 May and at Sizimesele Primary School on 10 June on disease transmission and control and use and care of the new sanitation system. An educational pamphlet, which can be found in Appendix E, was also distributed to learners at the presentations. In addition, an educational poster was designed and posted in each stall to reinforce learning about caring for the toilet and good hygiene practices. This poster was prepared in Zulu and can be found in Appendix F; the English translation of the poster is provided in Figure 6.2.

As user education had been provided to the households when their pour flush toilets were originally installed and they appeared to be managing their systems appropriately, it was not repeated in this study.

Figure 6.2 Educational poster which was posted in Zulu in each stall in the boys' and girls' toilet blocks at both schools.

The cleaning staff was provided with a cleaning rod to assist with unblocking the low flushes without damaging the fibre glass, should any blockages occur.

Figure 6.3 Cleaning rod provided to each school

7. USER EXPERIENCE

Interviews were conducted with 10 learners and three staff members at each school regarding their sanitation behaviour at home and at school, their perceptions of the new sanitation systems and the previous sanitation systems, and their knowledge and experience around disease transmission related to sanitation behaviour. Householders were asked only about their experience and behaviour with regard to their low flush systems.

7.1 Schools

At Thandaza High School 10 learners aged 17-19 and 3 staff members participated. At Sizimesele Primary School 12 learners aged 11-13 and three staff members participated. Four female teachers and 2 male teachers completed the interview. Their ages ranged from 31 to 49. The data below is combined for teachers at both schools.

Because the monitoring interval included just 5 weeks of use of the toilets for Sizimesele due to the delays in commissioning of the toilet blocks, the surveys conducted after commissioning were not repeated at the end of the study as the period was too short to provide a meaningful comparison over time.

7.1.1 Sanitation and behaviour around the toilet at home

Thandaza High School

Six of the ten learners indicated that they had flush toilets at home, one of whom had a second toilet which was a bucket toilet, and 4 had VIPs (actually these would have been Durban's Urine Diversion Double Vault toilets). For anal cleansing, half indicated that they only used toilet paper while 40% used both toilet paper and newspaper and 10% (1) only used newspaper. Eight indicated that they washed their hands after using the toilet while 2 indicated that they sometimes washed their hands after using the toilet. Half used soap, 2 sometimes used soap and 3 did not use soap at home. Seven indicated that they washed their hands at a tap, 2 in a dish and 1 in a sink. When asked if small children in the family sometimes defecated outside, 7 answered that they did not; 3 of these indicated that there were no small children in the family and 2 that small children were required to use the toilet only. Three indicated that young children sometimes defecated outside; in two cases the family covered the faeces with soil and in the third case they removed the faeces to the bucket toilet.

Sizimesele Primary School

Half of the respondents had VIPs (actually double vault urine diversion toilets) at home and half had flush toilets. One household used newspaper, another both newspaper and toilet paper and the rest (10) used only toilet paper. For washing hands 10 reported using a garden tap while 2 used a sink and 1 a dish. Six used soap always, 4 sometimes and 2 never. Only one boy reported that he did not wash his hands every time after using the toilet. Thirty percent (4) of the respondents indicated that children in the family sometimes defecate in the garden area surrounding the house: in 3 cases young children in the family regularly defecated outside and in the fourth water used from washing nappies was discarded in the garden. In 2 cases, the family removed the faeces with a spade and disposed of it in a

forested area adjacent to the house, while in the third case it was disposed of in a bucket toilet. When asked if anyone in the family ate soil, 33% (4) responded affirmatively. One respondent indicated that her sister, who is in her 20s, was told at the hospital that she needed iron and this is why she ate soil. She dug the soil from next to the house. Another reported that girls at school ate soil from a specific place on the school grounds. Another reported that a 10 month old baby in the family ate soil. The fourth reported that a female neighbour collected soil from next to the dam to eat.

Staff

All of the teachers reported having flush toilets at home and using only toilet paper for anal cleansing. Five indicated that they washed their hands at a sink and 1 at a tap. Four reported that they always washed their hands with soap – one indicated that she only used liquid soap – and 2 reported that they sometimes used soap. When asked if young children at their home sometimes defecated outside, 1 reported that a 2 year old in the household defecated outside and they moved the faeces to the edge of the property. Three indicated that small children were only allowed to use the toilet – one commenting (with an expression of disgust) that when she was small the adults told them to defecate outside but that now “we are not used to that kind of a life”. The remaining two indicated that there were no small children in the household. Only the staff at Sizimesele were asked if anyone in the household ate soil, as this question was added to the interview after the interviews at Thandaza had been completed. At Sizimesele, one staff member reported than an older woman in her family bought a white rocky substance called "white wash" to eat. The staff member said that this woman was addicted to this substance and if she wasn’t able to buy it she broke off pieces from a crumbling mud house to eat. The other two staff members reported that no one at the household ate soil and that they had not seen any of the learners engaging in this behaviour.

Summary of data

Responses from learners and staff at both schools are summarized in Table 7.1. Flush toilets were the most common type of sanitation at home, with all of the staff and 79% of combined staff and learners having flush toilets at home, with the remaining 21% having VIPs. Toilet paper was also the most commonly used type of anal cleansing material, with all staff and 75% of combined staff and learners using only toilet paper, 18% using both toilet paper and newspaper, and 7% using only newspaper.

The majority (89%) of respondents indicated that they always washed their hands after using the toilet, although failure to wash hands was likely to be underreported due to the fact that it would be socially disapproved; 7% indicated that they washed their hands sometimes and 4% (1 respondent) never. Slightly over half (54%) of respondents indicated that they always used soap when they washed their hands; 29% said that they sometimes used soap and 18% did not use soap to wash hands at their homes.

While the majority (71%) of respondents indicated that children in their families did not defecate outside, a large number of these did not in fact have small children in the family. The response of 29% of respondents that small children in their families did defecate outside does not account for those who might have allowed young children to defecate outdoors if there were young children in the family.
Only the learners and staff at Sizimesele were asked if someone in their household ate soil; among this group 33% answered yes.

Table 7.1 Interview responses regarding sanitation behaviour at home

Question	Thandaza HS	Sizimesele PS	Teachers	Combined (%)
Type of sanitation at home	4 VIP/ 6 F	6VIP / 6F	6F	21 VIP; 79 F
Type of anal cleansing material used	5TP, 4B, 1N	10TP, 1B, 1N	6TP	75 TP; 18 B; 7 N
Wash hands after use?	8Y, 2S	11Y, 1N	6Y	89 Y; 7 S; 4 N
Use soap?	5Y, 2S, 3N	6Y, 4S, 2N	4Y, 2S	54 Y; 29 S; 18 N
Children defecate outside?	3Y, 7N	4Y, 8N	1Y, 5N	29 Y; 71 N
Someone in household eats soil?	-	4Y, 8N	1Y, 2N	33 Y; 66 N

Y – yes/always, S – sometimes, N – no/never, B – both, F – flush, TP – toilet paper, N – newspaper

7.1.2 Perceptions of the old toilet block

The previous sanitation at Sizimesele Primary School was VIP toilets, with a standpipe for washing, and at Thandaza High School flush toilets and sinks.

Sizimesele Primary School

Before the construction of the new toilets the learners used portable chemical toilets, which had replaced a VIP block which was torn down. When asked what they liked or did not like about the previous toilets, half of the learners reported that they did not like the old toilets because they were dirty and because there was offensive/disturbing graffiti in them. It should be noted that both of these issues were within the control of the school. Issues raised which were related to the provision of the toilets were that they did not flush (3/10), with the result that faecal matter remained present possibly increasing the risk of disease (1/10) and that the seats were broken (1/10). Reasons learners did not like the toilets that related to user behaviour were that there was urine on the floor (4/10) or faeces on the floor (1/10), that learners abused them (2/10) and that they smelled unpleasant (1/10). None of the learners reported that there was anything that they liked about the old toilets, although one learner commented that he had been glad to have toilets at all.

Thandaza High School

Before the construction of the new toilets the learners used flush toilets which are now being kept in reserve. There were 3 toilets for the roughly 520 girls (ratio of 1:173) and 2 toilets plus a wall urinal for the roughly 365 boys (ratio 1:73). When asked what they liked or did not like about the previous toilets, 8 learners replied that they did not like the previous toilets because there were too few, 3 of these mentioned that because of this they would have to queue to use the toilet and 2 mentioned that the old toilets were broken. One of the learners commented that he preferred the wall urinal in the old toilet over the individual urinals in the new toilet block and that the seats in the old toilets were more comfortable, while 4 stated that they did not like anything about the previous toilets. One boy commented that he disliked the previous toilets because boys smoked in the toilets with the result that they smelled bad; he also said that bullies would force users to buy cigarettes from them in order to use the toilets.

Staff

Two staff members at Sizimesele said that they did not like the previous toilets because they were not clean. Other issues mentioned were that they were smelly, they attracted flies, they didn't flush and users put rubbish in the toilets.

At Thandaza, one staff member said that the old toilets were clean and had a toilet brush and soap and she had no criticism of them; another said she was happy that there were toilets at all. Two complained that the cisterns took a long time to fill between flushes; one mentioned that some of the flushers were broken. One respondent mentioned that there was only one loo for women and one for men, which was inadequate.

Summary of data

At Sizimesele, which previously had VIP toilets, more than half (7/13, 54%) of the staff and students interviewed said that they were unhappy with the previous toilets because they were dirty, while 31% (4/13) said that they did not like them because they didn't flush and 15% (2/13) because they smelled. At Thandaza, issues were around water pressure (2/13, 15%) and an inadequate number of toilets (9/13, 68%). Other issues focussed on disrepair and unpleasant behaviour on the part of other learners.

7.1.3 Perceptions of new toilet block

Sizimesele Primary School

When asked what they thought about the new toilets and whether there was anything they liked or didn't like about them, most of the respondents indicated that they liked having flush toilets (7/10), half that they liked the new toilets because they were clean. Other reasons given for liking the new toilets included that they had sinks (3/10), that they saved water (1/10), that they were sized for children (1/10), that the learners treated them with respect (1/10) and that there was no urine on the floor because there are urinals (1/10). Four of the learners stated that they liked "everything" about the new toilets and one described them as "beautiful".

Thandaza High School

When asked what they thought about the new toilets and whether there was anything they liked or didn't like about them, half responded that they liked the new toilets because there were more of them. Two described them as "perfect" and one liked them because they were near the classrooms while the other liked them because they had "fresh air". Three said that the new toilets needed mirrors while two said that they needed bins and soap.

Staff

When asked what they thought of the new toilets, 4/6 staff described the new toilets as "clean", 2 as "beautiful" and 1 as "perfect". One stated that there were at last enough toilets for staff. One mentioned that the new toilets were pleasant because the cisterns filled up faster, and another because they had sinks. Where they were dissatisfied with the new toilets was that they felt they needed mirrors and soap (2) toilet brushes (1) and disposal bins for feminine hygiene products (1). One expressed concern that the flushers might break.

Summary of data

At Sizimesele, where the school previously had VIPs and a standpipe for handwashing, 70% (7/10) of learner respondents (7/10) mentioned that they liked the new toilets because they flushed and 30% (3/10) because they had sinks.

7.1.4 Behaviour around the toilets at school

Thandaza High School

When asked whether they always flushed the toilet at school, 8 replied that they did and 2 that they sometimes did. When asked whether they always washed their hands after using the toilet, 7 replied that they always did and 3 that they sometimes did. All reported that they never disposed of rubbish in the toilet. When asked if they ever went to the toilet for any other reason, such as to smoke, chat to a friend, or be alone, 9 replied that they did not and 1 replied that he sometimes went to the toilet to be alone.

Sizimesele Primary School

When asked whether they always flushed the toilet at school 9 replied that they did, 1 said that he used the urinals only. When asked whether they always washed their hands after using the toilet, 8 replied that they always did, 3 that they sometimes did and 1 that she did not. All reported that they never disposed of rubbish in the toilet. When asked if they ever went to the toilet for any other reason, 2 replied that they sometimes did. When asked if they had ever seen learners defecate outside, all reported that they had not.

Staff

All 6 staff members interviewed indicated that they always flushed the toilet and washed their hands after using the toilet and that they never disposed of rubbish in the toilet or used it for other purposes**.**

Summary of data

Reporting of flushing and hand washing was high but may have been over-reported. Disposal of rubbish into the flush systems does not appear to be a concern, although this behaviour too may be underreported, as may be the use of the toilets for social and other functions.

Table 7.2 Interview responses regarding sanitation and hygiene behaviour at school

Question	Thandaza HS	Sizimesele PS	Teachers	Combined (%)
Always flush toilet?	8Y, 2S	12Y	6Y	93 Y, 7 S
Always wash hands?	7Y, 3S	8Y, 3S, 1N	6Y	75 Y, 11 S, 4N
Dispose of rubbish in toilet?	0Y, 10N	0Y, 12 N	6N	0
Use toilet for other purposes?	1Y,9N	2Y, 10N	6N	11 Y, 91N

Y – Yes, S – Sometimes, N – No

7.1.5 Perceptions of disease transmission

Sizimesele Primary School

When asked if they thought that it matters whether they washed their hands or not, and what could happen if they didn't wash their hands, 12/12 indicated that handwashing is important because germs

can get on your hands and make you sick. Sicknesses mentioned included stomach problems, diarrhoea, flu, TB, worms and cancer.

When asked whether they knew that people could get worms in their bodies, 8 answered that they did and 4 that they did not. When asked if they had ever had an experience with worms in their family, 8 responded that they had and 4 that they had not. One had experienced vomiting worms. Another reported a 16 year old brother having vomited brown worms which looked like "snakes" or "electrical cables". He was taken to the clinic and received medication. Another had a 9 year old sister who had passed "lots" of long, thin, brown worms which looked like "cables" in her faeces. She was given medication at the clinic. Another reported a 5 year old sister passing "whitish", thick, 15 cm long worms in her faeces. Another reported a brother who had passed brown worms 30-40 cm in length and as thick as electrical cable in his faeces. He was taken to the clinic and received medication; he was also told not to play in the soil. Another reported seeing a girl pass worms out of her face (nose and mouth?) which were shiny, silver, thick and about 20 cm in length. She was taken to the clinic.

When asked how a person gets worms, 7 said they didn't know. Other responses included that you could get worms by not being properly looked after (1), by eating sugar and cheese (1), by eating soil (1), by not washing hands after using the toilet (1), by drinking water from the sink in the loo (1) or by sitting on the loo too long (1). When asked what worms could do to a person, 7 said that they didn't know, 4 said that they could make you sick (3 specifically mentioned diarrhoea) and others said that the worms eat your food (1), make you constipated (1), make you unable to eat (1) or make you eat too much (1). When asked what a person can do to get rid of worms, 2 said they didn't know, 8 said that you can get medication at a clinic, 1 said you can buy medication and 1 said that you should make sure the toilet is clean. When asked how you can protect yourselves from worms, answers included: eat healthy things (1), go for check-ups at the clinic (2), take medicine to keep yourself protected (1), don't play in or eat soil (2), cover your face with a tissue when you cough (1), wash your hands after using the toilet (2), drink water (1), eat clean food and vegetables (1) and don't eat yoghurt, chips or sweets.

Thandaza High School

When asked if they thought that it matters whether they wash their hands or not, and what could happen if they didn't wash their hands, 6 responded that you could get germs that could make you sick if you didn't wash your hands. Three said that you could get diseases, including TB, cholera, flu and diarrhoea (2) and one said that you could pass germs on to young children if you didn't wash your hands.

When asked whether they knew that people could get worms in their bodies, 6 said yes and 4 said no, but when asked if they or someone in their family had ever had an experience with worms 4 said they had not, 2 said that they had heard of others having experiences, and 4 had witnessed a worm infection. One of these saw a child coughing up worms; worms were also seen in a child's faeces by two of the learners. Two described children vomiting worms. Two described the worms as looking like spaghetti, one that worms were as thick as her little finger, while another described the worms as being creamy white in colour and shaped like earth worms but with pointy ends. These are likely descriptions of *Ascaris lumbricoides*, or roundworm.

When asked how a person gets worms, 3 mentioned one of the ways one might get exposed to a worm infection, 3 gave incorrect responses and 4 said that they didn't know. Explanations provided by others included eating sugar, eating lots of maas, drinking dirty water, touching dirty things, not washing hands, not being clean and from dogs. When asked what worms can do to a person, half said that they did not know, 3 said that they can make you sick, 1 said that they can bite you and leave sores in your body, and 1 said that they will eat the food in your stomach. When asked how you could get rid of worms, half said that you can go to the clinic for treatment, 2 said that you should stay clean, 1 said that you can take castor oil or other treatments and 2 said that they don't know. When asked how you can protect yourselves from worms, 4 said wash your hands after going to the toilet, 1 said wash your hands before you eat, 1 said wash what you eat, 1 said don't eat lots of sugar, 1 said stay clean and 1 said keep the toilet clean.

Staff

When asked if they thought that it matters whether they wash their hands or not, and what could happen if they didn't wash their hands, all 6 staff expressed a basic understanding of disease transmission.

When asked whether they knew that people could get worms in their bodies, half said they did and half said they did not. When asked if they or someone in their family had ever had an experience with worms, 2 said they had and 4 said they had not. One described one child who had vomited brown worms which looked like "snakes" or "spaghetti" and another child who had passed 10 cm long worms in her faeces. The other mentioned a 5 year old child at home who had vomited worms which were "whitish" and "looked like spaghetti".

When asked how a person gets worms, 3 said they didn't know while others said by drinking dirty water (1), swimming in dirty water or eating half-cooked pork (1) or eating food without washing hands (1). When asked what worms can do to you, 3 said they didn't know; others replied that they can make you sick (1), cause diseases like bilharzia (1) or "eat whatever you're eating.". When asked how you can get rid of worms, all responded that you can go to the clinic or the doctor to get medication. When asked how you can prevent worm infestations, 2 said they didn't know; and the other three said by staying clean, adding that one should wash vegetables (1) and avoid using or swimming in dirty water.

Summary of data

Table 7.3 Interview responses relating to disease transmission

Question	Sizimesele PS	Thandaza HS	Teachers	Combined (%)
Understand disease transmission?	12/12	10/10	6/6	100
Know about worms?	8/12	6/10	3/6	61
Seen worms?	8/12	4/10	2/6	50
Know how you get worms?	2/12	3/10	3/6	29
Understand impact of worms?	5/12	4/10	3/6	43
Know how to get rid of worms?	9/12	5/10	6/6	71
Know how to avoid worms?	5/12	8/10	2/6	54

All respondents indicated a basic understanding that “germs” get onto hands and that these can make you sick. Many incorrect views about disease transmission were also expressed. Only 61% of respondents indicated that they knew about worms, while 50% reported having experienced or witnessed an incident with worms coming out of the body. Only 29% of responses regarding how one might get infected with worms were accurate, with many incorrect ideas voiced. The majority (71%) indicated that you could get rid of worms by taking medication obtained from the pharmacy or clinic, but only 54% were able to indicate any of the behaviours that would help to prevent a helminthic infection.

7.2 Private homes

Householders were asked about their experience with their low flush systems on 25 July, after 4 months of use. One household has 4 members and the other 6. The head of both households (both retired males) reported that they had had no blockages or other problems and expressed satisfaction with their systems. Both use only toilet paper for anal cleansing. Both reported that they had no problems with their systems smelling and that they found their toilets easy to keep clean.

8. CONCLUSIONS

The low flush system designed in this study was found to offer an alternative which has the potential to meet a number of the needs of both municipalities and users which are not addressed by existing basic sanitation systems.

Dignity

Users of VIP toilets have identified a number of practical factors which make them dissatisfied with the VIP:

- while the smell may be improved over a homebuilt pit latrine, the toilet does still have an unpleasant smell
- being able to see excreta and insects below you when using the toilet is unpleasant
- direct access to the pit through the toilet seat raises a concern that small children could fall into the pit while using the toilet. (This issue has an additional negative impact in that some parents encourage their children to defecate outside for reasons of safety, which then introduces faeces into the living environment and increases the potential for diseases).

The low flush system addresses the desire of users for "equality" in sanitation – where dry sanitation systems are perceived as inferior to waterborne sanitation and which some experience as a form of discrimination in which the injustices of the past have not been rectified – by providing a flush toilet which can perform well within the limitations existing in some communities which make full waterborne sanitation impractical. It provides a greater sense of cleanliness than does a pit latrine by removing the sight and smell of faecal material away from the user. The presence of the pan eliminates the concern of a child falling into the pit. While users may still experience an unpleasant smell from the system during hot weather due to the close proximity of the pit, issues of smell are far improved over a pit latrine, allowing the toilet to be installed inside the house if desired.

Environmental sustainability

In this study the low flush toilet performed well with a 2.5 litre flush, representing a 40% to 70% saving of water over standard toilets. It is possible this could be reduced further without any negative consequences. This represents a significant saving of water over a standard flush toilet and the development of low flush technology points a way forward for sanitation design which in its current form is unsustainable. If, in addition, a cistern is used which does not store water between flushes, water losses due to leaking seals would be eliminated as well. Finally, on-site sanitation reduces the risks of pollution that can result when blockages occur in reticulated sewerage systems, keeping problems contained to the immediate environment.

Versatility

The low flush system can be installed as an upgrade to a VIP latrine, a pour flush toilet or can replace a standard flush toilet linked to a septic tank if desired. The system can be installed indoors, providing greater convenience and safety to household members, but can also be installed in an existing VIP structure outside if there is not space for the toilet in the house. It is a practical option both in rural areas where sewering sparsely settled areas is too costly, and in informal settlements where sewering densely settled areas is not feasible. An alternative to collecting sludge in a soak pit is connecting the

system to a small bore sewer which removes effluent to a digestor or small treatment plant. The system has performed well on a small scale in both residential and institutional contexts.

Durability

The low flush system performed well when tests were done in which newspaper was flushed along with faecal samples. Users of the pour flush units which have been in use for 18 months to approximately 3 years have indicated that they have not experienced any difficulty when flushing newspaper. This meets an important criterion for basic sanitation in South Africa, where many users cannot afford toilet paper. Previous low flush systems relied upon educating users to use only toilet paper. However given the financial constraints of many families this was not practical, with the result that systems blocked and users have been forced to buy toilet paper even though this is not sustainable for them. Further modification is needed to arrive at a model suitable for injection moulding which performs well with newspaper.

Moving beyond a "one size fits all" model

With the low flush system priced in the same range at the VIP, it allows municipalities to offer users a choice of sanitation options rather than imposing a single model on everyone, with the result that users may resent the system they are given and may not care for it adequately. In a situation where municipalities are under pressure from communities to provide waterborne sewerage and this is not feasible, the low flush may represent an acceptable option to all. In communities where a single sanitation design has already been provided, the low flush system provides an option for users who are dissatisfied with their systems to convert to a low flush on their own initiative.

Improved pit emptying or sludge treatment

The difficulty with emptying pit latrines is a problem which is now beginning to hit municipalities with force as sanitation systems that were built in the past decade begin to reach capacity. The main difficulties with emptying VIPs are that the sludge is too dry and full of rubbish for pumping, requiring it to be shovelled out manually, which puts the health of workers at greater risk. The addition of a small quantity of water to the sludge in a low flush system results in a slightly wetter, more homogenous sludge which can be pumped. Because the pedestal does not provide direct access to the pit in the way that the pedestal of a VIP does, users are discouraged from disposing of solid waste into the pit, resulting in a nearly rubbish-free sludge which is unlikely to clog a vacuum tanker. In addition, twin pits can be constructed so that while the second pit is put to use sludge in the first pit can be left to degrade and dewater, reducing the volume of the sludge. Alternatively, low flush sludge can be removed via a small bore sewer to a digestor or a small treatment plant, eliminating the risk of environmental contamination during pit emptying and reducing the risk of workers coming into contact with sludge.

Sanitation behaviour, health and hygiene

It was found that even in these rural areas the majority (79%) among 28 respondents had flush toilets at home and 75% of respondents used toilet paper; only 2 respondents (7%) used newspaper exclusively, while the rest used both. Because families are electing to use flush toilets and toilet paper of their own accord, most learners are already accustomed to the behaviour required for flush toilets (e.g. not

throwing rubbish in the toilet) when they come to school, making the transition from pit latrines to low flush at schools an easier shift.

While most respondents used soap when they wash their hands, a significant number did not. Soap is not provided to learners at the schools because of the likelihood that it will quickly disappear. As handwashing is more effective with soap, this is not ideal.

Open defecation was reported at nearly a third of homes, and is probably more commonly accepted than that as it is usually young children who defecate in the open and many of the respondents who reported that open defecation does not occur at their homes did not have small children in their families. This is a serious concern because it undermines the purpose of providing sanitation at all, which is to prevent contact between people and faecal matter. Faecal matter in the home environment can be a source of diseases, including potentially dangerous diarrhoeal diseases and intestinal worms. The eggs of intestinal worms are extremely hardy and can remain viable in a soil environment for a considerable length of time. Further compounding this risk, a third of the small group of respondents indicated that someone in their household eats soil. If this soil is taken from the household environment and open defecation is also practiced at the household, the risk of infection is even greater.

9. RECOMMENDATIONS

Design and production

At the time of publication of this report, the development of a suitable prototype low flush pedestal for injection moulding is well advanced. After the costs for production of the mould are covered the price of per pour flush / low flush pedestal can be brought down to the same range as the cost of a VIP pedestal.

There is a need for an affordable, reliable and robust cistern which is designed to provide a 1 to 3 litre flush. In this trial the low flush was achieved by bending the arms of cisterns designed to provide a 4.5 litre flush, which is not idea.

Larger scale piloting

Low flush technology is ready for piloting on a larger scale in both residential and institutional contexts. The particular advantages of the low flush system would make it an appropriate option to be considered for the following contexts:

- Rural or urban schools
- Community or public ablution blocks
- Other institutional contexts
- Homes where householders are seeking an upgrade to an onsite flush system
- Communities where existing sanitation systems have failed or been rejected.

It is essential that wherever low 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.

Promoting sanitation options that use water responsibly

In a number of other countries, environmental consciousness is spurring an interest in and shift towards new sanitation options, including even dry systems. Despite the fact that South Africa is a water scarce country, there have not yet been serious initiatives to move away from full flush water borne sewerage systems here. A low flush toilet which is initially aimed at households which do not have access to a sewer connection could also be promoted as a more environmentally responsible option for conversion from full waterborne sanitation. By introducing a viable low flush toilet which uses a fraction of the water used by a standard flush toilet, the foundation would be laid for a broader shift towards sanitation options which use water resources more responsibly.

Municipal planning for sludge removal and disposal

It is vital that municipalities think through the entire sanitation cycle – from construction to eventual emptying and re-commissioning – before selecting a sanitation system. Many municipalities will soon be faced with a crisis of full pit latrines with no viable method for either removing the sludge from the pit

or disposing of the sludge. Large volumes of pit latrine sludge cannot be disposed of at wastewater treatment works, and is therefore even more problematic than sewage; some municipalities have begun stockpiling sludge. The sludge produced in a low flush system, however, can be removed using standard vacuum methods or via small-bore sewer and is suitable for a wide range of beneficial disposal options. For schools in the eThekwini Metropolitan Municipality, the municipality could, for example, process the raw sludge at its sludge pelletising plant, producing a pasteurized sludge pellet which can be used as a fertilizer.

Sanitation behavior, health and hygiene

In interviews conducted in this study it was found that the majority of households have flush toilets and use toilet paper. This suggests that flush toilets are desired and that some householders are installing flush toilets on their own initiative. Low flush technology represents a more environmentally sustainable option than a full flush toilet and does not require a full septic tank system but can function safely with a simple leach pit. Low flush technology is also cheaper than an onsite full flush system, and so would be within the reach of more people who are aspiring to flush systems. The fact that learners have flush toilets at home also eases the transition to low flush technology where it is implemented in schools.

The use of soap while washing hands improves the removal of faecal matter and microbes from the hands significantly. It is vital that schools provide soap to learners and model this in order to influence behaviour at home as well.

Open defecation is a serious problem, reported at nearly a third of homes by respondents in this study. In addition, a third of respondents in a smaller sample indicated that someone in their household practices geophagia (soil eating). These two behaviours, particularly in combination, put householders at risk for ongoing transmission of diseases and helminthic infections. It is typically young children that are encouraged or allowed to defecate in the open, and this may be due at least partly to concerns of parents that a young child could fall through the toilet seat into the pit while using a VIP. Low flush technology addresses this risk, and may curb the practice of open defecation if combined with education. Also, parents may feel more comfortable directing their young child to use an indoor toilet independently than a toilet in a separate structure which may be some distance from the house. Again, low flush technology offers the option of installing the toilet inside the house, which may overcome issues of convenience or safety for families with regard to using outdoor sanitation.

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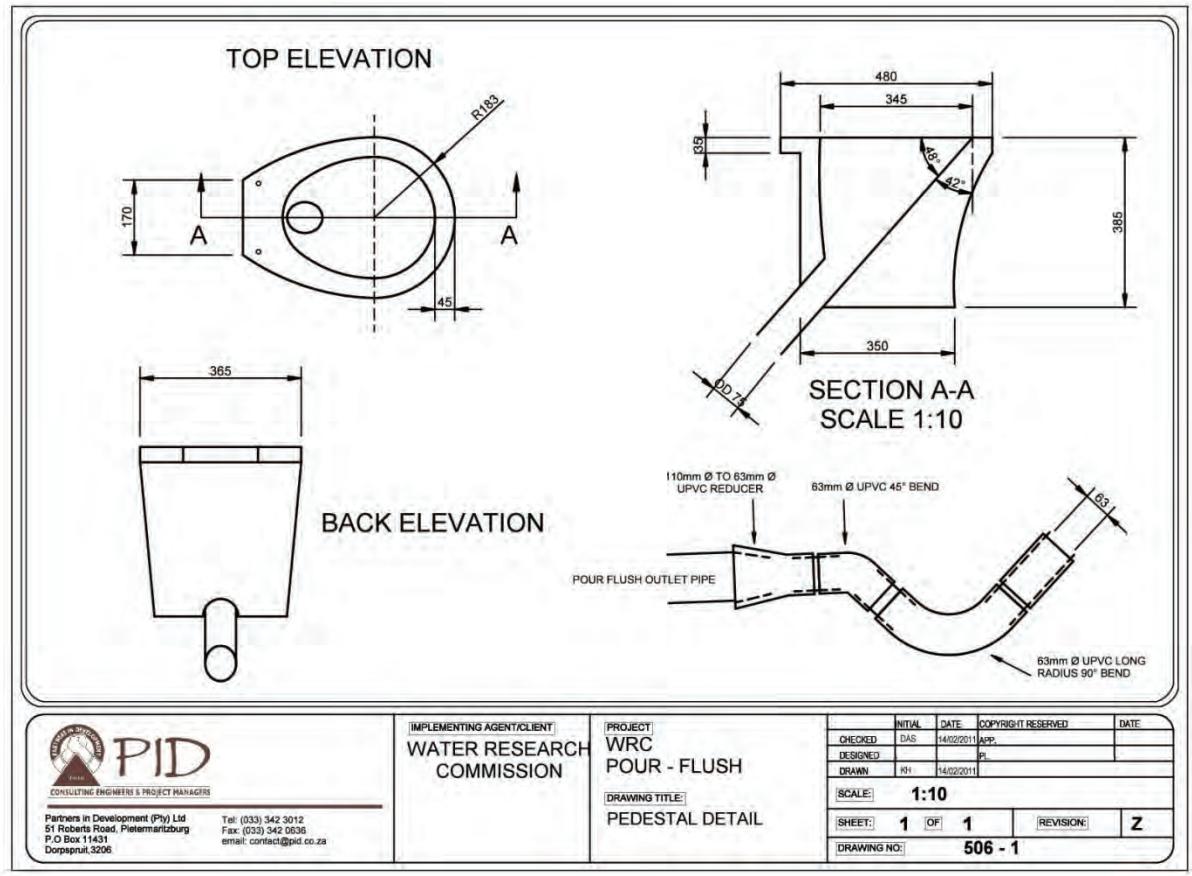
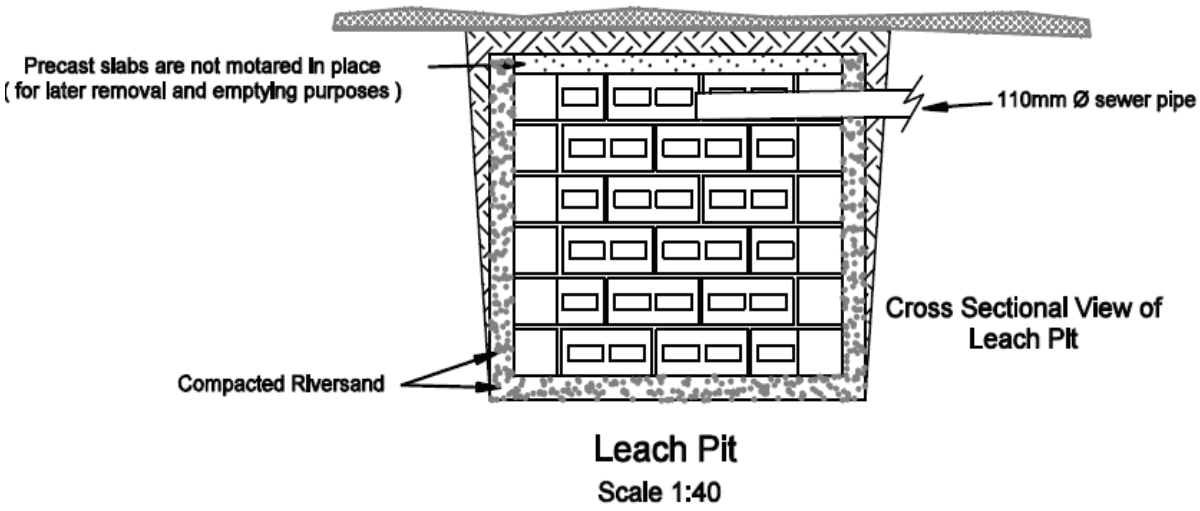
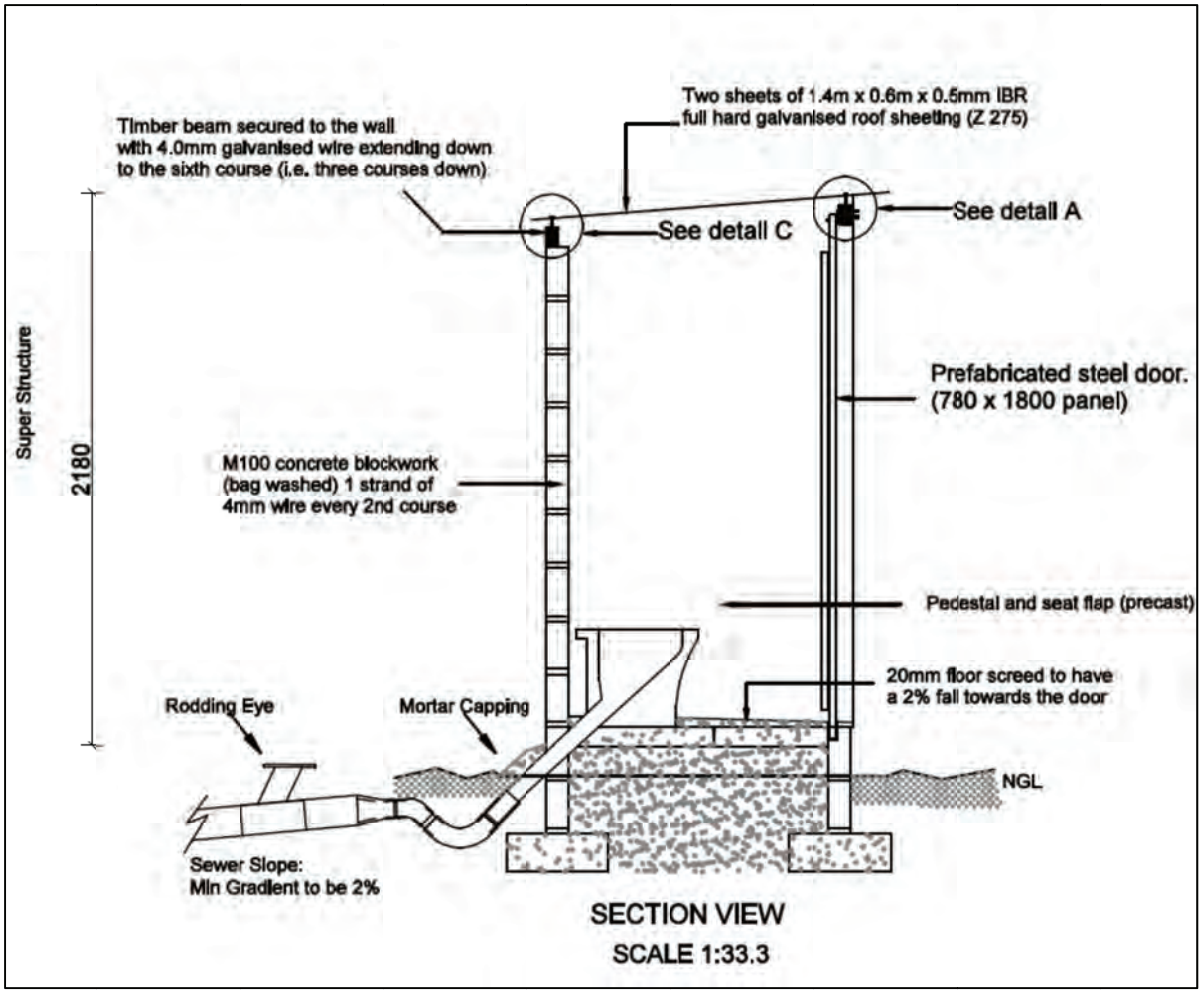
Appendix A: Details for pour flush / low flush pedestal and pit



Pour flush / low flush pedestal





Pour flush / low flush top structure and sewer

Appendix B: Testing the prototypes

Testing the first prototype

With toilet paper

Cistern 300 mm above pan (with toilet paper)

Flush Volume (ℓ)	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	2	2	4	4	2
1.5	4	4	3	1	4	4
2	6	6	0	5	6	6
2.5	6	6	6	6	6	6
3	6	6	6	6	6	6

Cistern 600 mm above pan (with toilet paper)

Flush Volume (ℓ	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	0	0	0	0	0
1.5	4	4	3	1	4	4
2	6	6	6	6	6	6
2.5	6	6	6	6	6	6
3	6	6	6	6	6	6

Cistern 900 mm above pan (with toilet paper)

Flush Volume (ℓ	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	1	0	1	0	0
1.5	4	4	3	1	4	4
2	6	6	6	1	6	6
2.5	6	6	6	6	6	6
3	6	6	6	6	6	6

Testing first prototype with newspaper

Cistern 300 mm above pan (with newspaper)

Flush Volume(ℓ)	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	0	0	0	0	0
1.5	4	0	4	0	0	0
2	1	2	2	3	3	2
2.5	6	6	6	6	6	6
3	6	6	6	6	0	6

Cistern 600 mm above pan (with newspaper)

Flush Volume(ℓ)	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	0	0	0	0	0
1.5	4	0	4	0	0	0
2	6	6	0	0	2	2
2.5	6	2	6	1	6	6
3	0	6	6	6	6	6

Cistern 900 mm above pan (with newspaper)

Flush Volume(ℓ)	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1	0	0	0	0	0	0
1.5	4	0	4	0	0	0
2	0	1	3	0	6	1
2.5	6	6	6	6	6	6
3	6	6	6	6	6	6

Testing the second prototype

With toilet paper

Cistern 300 mm above pan (with toilet paper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	0	0	0	0	0
1.5 ℓ	4	3	2	4	2	3
2 ℓ	6	5	6	6	6	6
2.5 ℓ	6	6	6	6	6	6
3 ℓ	6	6	6	6	6	6

Cistern 600 mm above pan (with toilet paper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	1	1	1	1	1
1.5 ℓ	4	1	0	0	4	1
2 ℓ	5	2	5	6	5	5
2.5 ℓ	6	5	6	4	4	5
3 ℓ	6	6	6	6	6	6

Cistern 900 mm above pan (with toilet paper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	0	0	0	0	0
1.5 ℓ	0	1	0	1	0	0
2 ℓ	0	4	2	1	6	2
2.5 ℓ	5	6	5	3	5	5
3 ℓ	6	6	6	6	6	6

Test Results (Prototype 2) – with newspaper

Cistern 300 mm above pan (with newspaper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	0	1	2	0	0
1.5 ℓ	2	0	1	0	2	1
2 ℓ	4	2	6	2	4	4
2.5 ℓ	6	6	6	4	6	6
3 ℓ	6	6	5	6	6	6

Cistern 600 mm above pan (with newspaper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	0	0	0	0	0
1.5 ℓ	1	0	0	0	0	0
2 ℓ	2	0	0	2	0	0
2.5 ℓ	3	6	3	3	6	3
3 ℓ	6	6	6	6	6	6

Cistern 900 mm above pan (with newspaper)

Flush Volume	Test 1	Test 2	Test 3	Test 4	Test 5	Median
1 ℓ	0	0	0	0	0	0
1.5 ℓ	0	0	0	1	0	0
2 ℓ	0	4	1	0	0	0
2.5 ℓ	1	4	4	6	4	4
3 ℓ	6	6	6	6	6	6

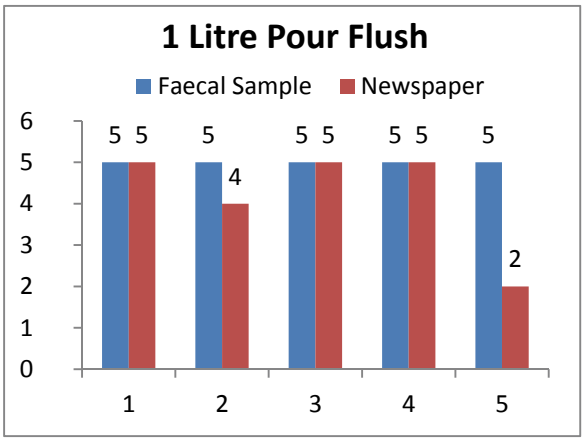
First test of the third prototype without modifications

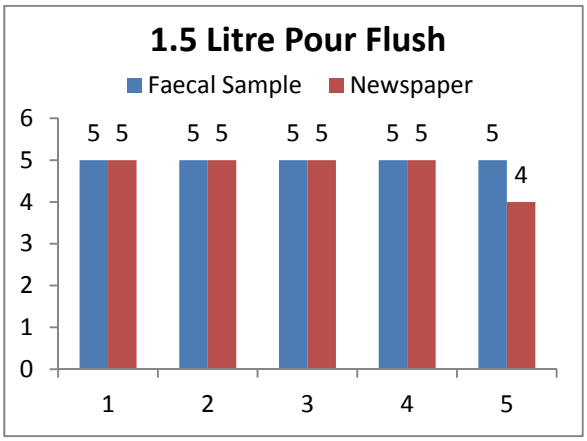
With 5 Faecal Samples & 5 Newspaper

Testing with a pour flush

1 litre Pour Flush		
	Faecal Sample	Newspaper
1	5	5
2	5	4
3	5	5
4	5	5
5	5	2
Average	**5**	**4.2**

1.5 Litre Pour Flush		
	Faecal Sample	Newspaper
1	5	5
2	5	5
3	5	5
4	5	5
5	5	4
Average	**5**	**4.8**



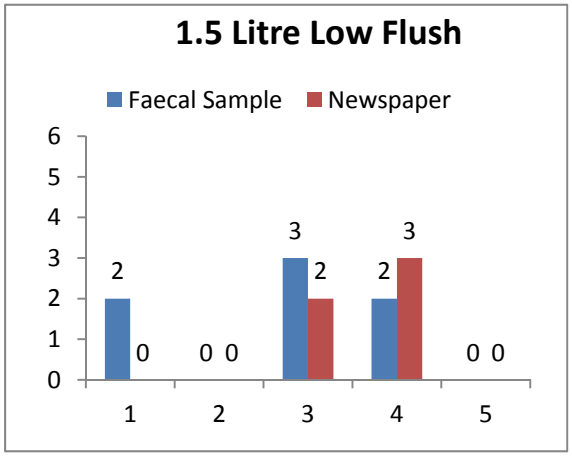


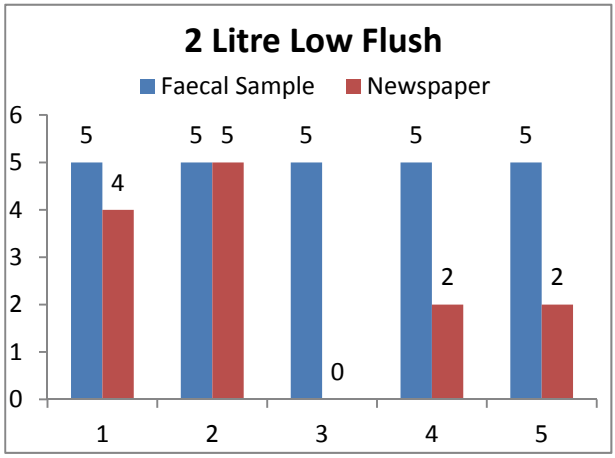
Low flush tests

No faecal samples or newspaper passed through the system with a 1 litre flush.

1.5 Litre Low Flush		
	Faecal Sample	Newspaper
1	2	0
2	0	0
3	3	2
4	2	3
5	0	0
Average	**1.4**	**1**

2 Litre Low Flush		
	Faecal Sample	Newspaper
1	5	4
2	5	5
3	5	0
4	5	2
5	5	2
Average	**5**	**2.6**

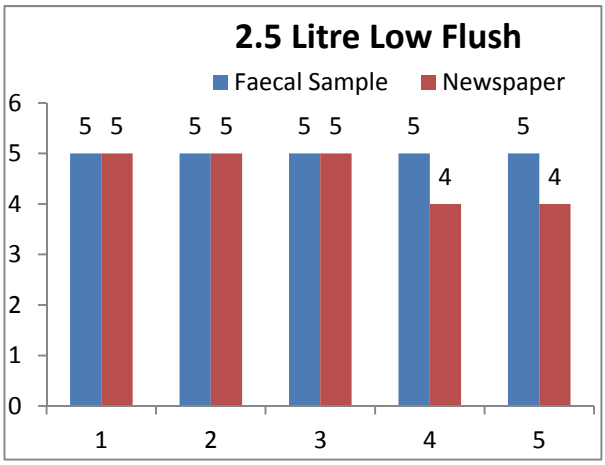


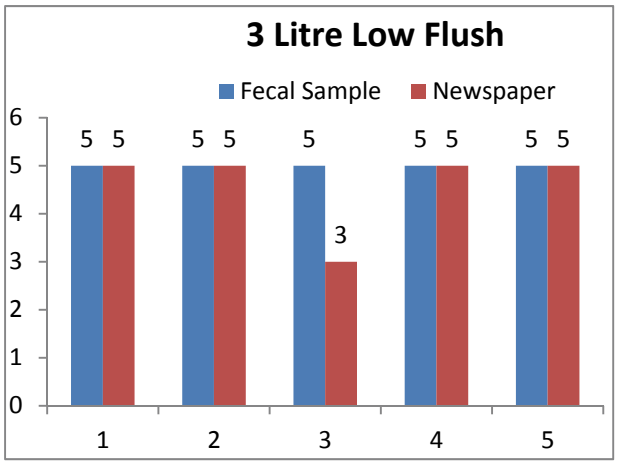


2.5 Litre Low Flush		
	Faecal Sample	Newspaper
1	5	5
2	5	5
3	5	5
4	5	4
5	5	4
Average	5	4.6

3 Litre Low Flush		
	Faecal Sample	Newspaper
1	5	5
2	5	5
3	5	3
4	5	5
5	5	5
Average	5	4.6

Average number of faecal and newspaper samples passed through system for 5 flushes





Second test of the third prototype, with modifications on 24 July, 2013

Test 1:

No changes made to prototype
Tissue 3x10 sheets of single ply toilet paper folded 3 times
Newspaper – 3x1/4 sheet of newspaper crumpled and folder once
Condoms – 5x soya paste filled condoms for faecal samples

1 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	0	0	**1**	0	0
2	0	0	**2**	0	0
3	0	0	**3**	0	0
4	0	0	**4**	0	0
5	0	0	**5**	0	0
AVE.	**0**	**0**	**AVE.**	**0**	**0**

1.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	1	3	**1**	0	0
2	0	5	**2**	0	0
3	1	3	**3**	0	0
4	2	3	**4**	0	0
5	0	0	**5**	0	0
AVE.	**0.8**	**2.8**	**AVE.**	**0**	**0**

2 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	0	5	**1**	0	4
2	0	4	**2**	0	4
3	2	5	**3**	0	5
4	2	5	**4**	0	5
5	3	5	**5**	0	3
AVE.	**1.4**	**4.8**	**AVE.**	**0**	**4.2**

2.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	0	5
2	3	5	**2**	0	5
3	2	5	**3**	0	5
4	3	5	**4**	0	5
5	3	5	**5**	0	4
AVE.	**2.8**	**5**	**AVE.**	**0**	**4.8**

3 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	-	-	**1**	0	5
2	-	-	**2**	0	5
3	-	-	**3**	0	5
4	-	-	**4**	1	5
5	-	-	**5**	0	5
AVE.			**AVE.**	**0.2**	**5**

3.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	-	-	**1**	2	5
2	-	-	**2**	1	5
3	-	-	**3**	2	5
4	-	-	**4**	1	5
5	-	-	**5**	0	5
AVE.			**AVE.**	**1.2**	**5**

4 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	-	-	**1**	3	5
2	-	-	**2**	2	5
3	-	-	**3**	2	5
4	-	-	**4**	3	5
5	-	-	**5**	3	5
AVE.			**AVE.**	**2.6**	**5**

2 Litre – Low Flush						
	Flush 1		Flush 2		Total	
Test	Newspaper	Faecal sample	Newspaper	Faecal sample	Newspaper	Faecal sample
1	0	0	0	5	0	5
2	0	0	0	0	0	0
3	2	0	0	4	2	4
4	2	5	1	5	3	10
5	1	4	0	1	1	5
AVE.	**1**	**1.8**	**0.2**	**3**	**1.2**	**4.8**

2.5 Litre – Low Flush						
	Flush 1		Flush 2		Total	
Test	Newspaper	Faecal sample	Newspaper	Faecal sample	Newspaper	Faecal sample
1	1	5	2	0	3	5
2	0	5	0	0	0	5
3	0	5	1	0	1	5
4	2	5	1	0	3	5
5	0	5	0	0	0	5
AVE.	**0.6**	**5**	**0.8**	**0**	**1.4**	**5**

Test 2:

Condoms – 5x soya paste filled condoms for faecal samples
Tissue 3x10 sheets of single ply toilet paper folded 3 times
Newspaper – 3x1/4 sheet of newspaper crumpled and folder once
Condoms – 5x soya paste filled condoms for faecal samples

2 Litre – Low Flush					
Test	Toilet paper	Faecal sample	Test	Newspaper	Faecal sample
1	2	5	**1**	0	5
2	2	5	**2**	0	5
3	3	5	**3**	0	5
4	3	5	**4**	0	5
5	2	5	**5**	0	5
AVE.	**2.4**	**5**	**AVE.**	**0**	**5**

2.5 Litre – Low Flush					
Test	**Tissue**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	1	5
2	3	5	**2**	0	5
3	3	5	**3**	0	5
4	3	5	**4**	0	5
5	3	5	**5**	0	5
AVE.	**3**	**5**	**AVE.**	**0.2**	**5**

Test 3. Modifications:

25x3 mm dia. Holes added to rim, with foam added to reduce rim volume
Tissue 3x10 sheets of single ply toilet paper folded 3 times
Newspaper – 3x1/4 sheet of newspaper crumpled and folder once
Condoms – 5x soya paste filled condoms for faecal samples

2 Litre – Low Flush					
Test	**Tissue**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	0	5	**1**	1	5
2	3	5	**2**	0	5
3	2	5	**3**	0	5
4	2	5	**4**	0	5
5	3	5	**5**	0	5
AVE.	**2**	**5**	**AVE.**	**0.2**	**5**

2.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	0	5
2	3	5	**2**	0	5
3	3	5	**3**	0	5
4	3	5	**4**	1	5
5	3	5	**5**	0	5
AVE.	**3**	**5**	**AVE.**	**0.2**	**5**

3 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	2	5
2	3	5	**2**	3	5
3	3	5	**3**	0	5
4	3	5	**4**	3	5
5	3	5	**5**	0	5
AVE.	**3**	**5**	**AVE.**	**1.6**	**5**

3.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	2	5
2	3	5	**2**	1	5
3	3	5	**3**	3	5
4	3	5	**4**	3	5
5	3	5	**5**	3	5
AVE.	**3**	**5**	**AVE.**	**2.4**	**5**

4 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1			**1**	3	5
2			**2**	3	5
3			**3**	2	5
4			**4**	2	5
5			**5**	2	5
AVE.			**AVE.**	**2.4**	**5**

Test 4. Modifications:

43x3 mm dia. Holes added to rim, with foam added to reduce rim volume
Tissue 3x10 sheets of single ply toilet paper folded 3 times
Newspaper – 3x1/4 sheet of newspaper crumpled and folder once
Condoms – 5x soya paste filled condoms for faecal samples

2 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	2	5	**1**	0	5
2	1	5	**2**	0	5
3	2	5	**3**	0	5
4	2	5	**4**	1	5
5	2	5	**5**	0	5
AVE.	**1.8**	**5**	**AVE.**	**0.2**	**5**

2.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	2	5	**1**	0	5
2	3	5	**2**	0	5
3	2	5	**3**	1	5
4	1	5	**4**	0	5
5	2	5	**5**	1	5
AVE.	**2**	**5**	**AVE.**	**0.4**	**5**

3 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	1	5
2	3	5	**2**	1	5
3	3	5	**3**	1	5
4	3	5	**4**	0	5
5	3	5	**5**	1	5
AVE.	**3**	**5**	**AVE.**	**0.8**	**5**

3.5 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1	3	5	**1**	3	5
2	3	5	**2**	2	5
3	3	5	**3**	3	5
4	3	5	**4**	1	5
5	3	5	**5**	2	5
AVE.	**3**	**5**	**AVE.**	**2.2**	**5**

4 Litre – Low Flush					
Test	**Toilet paper**	**Faecal sample**	**Test**	**Newspaper**	**Faecal sample**
1			**1**	3	5
2			**2**	2	5
3			**3**	3	5
4			**4**	3	5
5			**5**	3	5
AVE.			**AVE.**	**2.8**	**5**

Appendix C: Water consumption monitoring record

Sizimesele Primary School

Sizemesele	Boys' Block	
PF 1	Lowest flush volume/10:	2.2
	Highest flush volume/10:	3.3
	Mean flush volume	2.8

Date	Reading	Litres used	Litres/ week	Flushes/ week
20/5	856			
27/5	1347			
10/6	2508			
15/7	2880	2024	405	144

Sizemesele	Boys' Block	
ST 2	Lowest flush volume/6:	4.1
	Highest flush volume/6:	4.7
	Mean flush volume	4.35

Date	Reading	Litres used	Litres/ week	Flushes/ week
20/5	567			
27/5	999.5			
10/6	1683			
15/7	2410	1843	369	85

Sizemesele	Girls' Block	
PF 2	Lowest flush volume/10:	2.5
	Highest flush volume/10:	2.8
	Mean flush volume	2.5

Date	Reading	Litres used	Litres/ week	Flushes/ week
20/5	554			
27/5	742			
10/6	1152			
15/7	1675	1121	224	90

Note: There were 8 calendar weeks in the monitoring
period, however 3 of these fell in the school holidays so
only 5 weeks have been counted.

The meters on the remaining 5 toilets in the girls' block
failed to work. The number of flushes recorded for PF2
may be expected to be higher for PF1.

Thandaza High School

Thandaza	Boys' Block	
PF 1	Lowest flush volume/10:	1.7
	Highest flush volume/10:	2.7
	Mean flush volume	2.35

Date	Reading	Litres used	Litres/ week	Flushes/ week
22/4	701			
29/4	1026			
10/5	1494			
24/5	2059			
10/6	2494			
15/7	2708	2007	223	95

Thandaza	Boys' Block	
ST 2	Lowest flush volume/5:	3.9
	Highest flush volume/5:	4.3
	Mean flush volume	4.1

Date	Reading	Litres used	Litres/ week	Flushes/ week
22/4				
29/4				
10/5	10240			
24/5	15937			
10/6	35935			
15/7	40268	30028	3336	814

Thandaza	Girls' Block	
PF 1	Lowest flush volume/5:	2.3
	Highest flush volume/5:	3
	Mean flush volume	2.5

Date	Reading	Litres used	Litres/ week	Flushes/ week
24'4	1568			
29/4	2053			
10/5	24390			
24/5	30719			
10/6	32729			
15/7	33824	32256	3584	1433

Thandaza	Girls' Block	
ST 3	Lowest flush volume/10:	4.2
	Highest flush volume/5:	4.7
	Mean flush volume	4.5

Date	Reading	Litres used	Litres/ week	Flushes/ week
22/4				
29/4				
10/5	1920			
24/5	8813			
10/6	18042			
15/7	18839	16919	2417	537

Thandaza	Girls Block	
PF 2	Lowest flush volume/4:	2.3
	Highest flush volume/4:	2.7
	Mean flush volume	2.4

Date	Reading	Litres used	Litres/ week	Flushes/ week
24'4	418			
29/4	3660			
10/5	4263			
24/5	12160			
10/6	38209			
15/7	38485	38067	4229	1762

The period 22/4 - 15/7 covers 12 weeks; 3 of these fell in the holidays however (24/6-14/7) and so have been deducted from the week count.

The higher use of the two low flush toilets may be accounted for by the fact that they are the first two stalls as users enter the toilet block.

Appendix D: Interview for principal

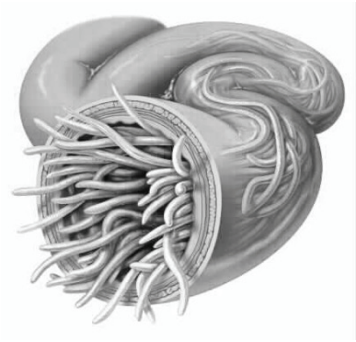
1. School:
2. Built:
3. Previous sanitation (type, number boy/girl, male/female), handwashing facilities, provision of t.p.
   3.1. No of students (boys/girls)
   3.2. No of teachers (male/female)
   3.3. Issues around previous sanitation
   3.4. Smell
   3.5. Cleanliness
   3.6. Blockages
   3.7. Vandalisms
   3.8. Cleaning routine: how often, what products, what was cleaned (walls, floors)
   3.9. Provision of t.p., soap, towels, waste baskets
   3.10. Maintenance/repairs
4. New toilets: feelings, issues
5. Provision of anal cleansing material:
6. What are kids instructed to do re: anal cleansing material
7. Issues
   - Smell
   - Cleanliness
   - Blockages
   - Vandalism
8. Cleaning routine: how often, what products, what was cleaned (walls, floors)
9. Provision of t.p., soap, towels, waste baskets
10. Maintenance/repairs
11. Disposal of rubbish:
12. Concerns about new toilets (e.g. Water supply)
13. GPS coordinates

Appendix E: User education pamphlet

DISEASES FROM POO

Microorganisms in poo can give you various sicknesses. Some of these cause diarrhoea. There are also worm eggs in poo. These get into the soil and onto surfaces from poo. If germs and eggs get on your hands you can swallow them without knowing it.

WORMS. Most kids in KwaZulu-Natal have worms. Worms use the nutrients you need. The result can be that you are **LESS CLEVER** and **DON'T GROW WELL**.



Roundworm in a person's intestine

- **HOW DO YOU GET WORMS?** You get worms by swallowing their eggs which are too small to see. Their eggs come out of human or animal poo and get on your hands from touching dirty things and get from your hands into your mouth.

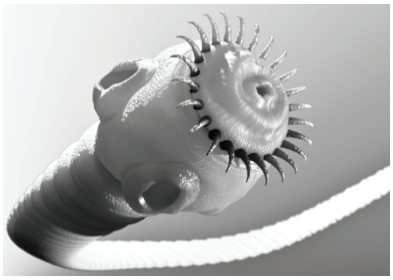
- **WHAT CAN I DO TO GET RID OF WORMS?**
  Buy deworming treatment at a pharmacy or get it free at a clinic. It is called Mebendazole. If you think you and your family have worms it is a good idea for everyone in the family to take deworming tablets twice a year.

Roundworm coming out of a child's nose and mouth

- **HOW CAN I KEEP FROM GETTING WORMS?**
  Wash your hands with soap after going to the toilet or touching the soil. Don't let any child poo outside – poo must always go in the toilet. Don't let kids play where animals have pooed.

DIARRHOEA can be deadly for young kids, old people and sick people.

If someone in your family has diarrhoea, make this recipe for them:
1 Litre water + ½ spoon salt (2.5 ml) + 6 spoons sugar (30 ml)



Head of a tapeworm

Appendix F: User education poster

Appendix G: Low flush toilet users questionnaire

Name: _____ Date: _____ Age _____

A. Introduction

My name is _____. I work for Partners in Development, which is an engineering firm in Pietermaritzburg. We built the new water saving toilets in your toilet block. I would like to ask you some questions about your opinions about hygiene and diseases. You can skip any question that you would rather not answer. We won't be using your name or initials with any information you give us.

B. Home behaviour:

1. What kind of toilet do you have at home?
2. What does your family use for wiping material?
3. What kind of place do you have to wash your hands (tap/basin)?
4. Do you usually have soap to wash hands?
5. Do you yourself wash your hands after using the toilet?
6. Do small children in your family sometimes poo outside?
7. Does anyone in the family eat soil? Where do they take it from?

C. School behaviour:

8. What do you think about the new toilets compared to the old? Is there anything you don't like about them?
9. Do you always flush the toilet after you use it or sometimes forget?
10. Do you always wash your hands after you use the toilet at school or do you sometimes forget?
11. Do you ever put rubbish in the toilet?
12. Do you go to the toilet for any other reason (smoke, cry, chat privately to friend)
13. Do you ever see children defecate on the floor or outside?

D. Views about disease transmission:

14. Do you think it matters if you wash your hands or not? Why? What might happen if you don't wash your hands?
15. Do you know that people can get worms in their stomachs?
16. Did you ever have an experience with worms in your family?
17. How do you think people get worms?
18. What can worms do to you?
19. How can you get rid of worms?
20. What can you do to protect yourself from worms?

21. Does anyone eat soil at home? From where? Or have seen/heard of people doing this?
22. Does anyone miss school or have issues at school because of menstruation? What can the school do to support them?