Semana temática: Agua y ciudad

Eje temático: Pautas de los gobiernos locales para la sostenibilidad

Título de la ponencia: *Performance of an ultra-low flush toilet (Comportamiento de una cisterna de baño de muy baja descarga).*

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Resumen:

A key challenge in water management over the coming decades is the issue of limiting the consumption of water in the domestic environment, without reducing levels of service. Quantification of the components of domestic demand highlights toilet flushing as taking the major share of potable water consumption (30%), making it an obvious target for improved water efficiency. This paper presents the results of a work package of the WaND research consortium (www.wand.uk.net) concerned with the field and laboratory evaluation of a prototype ultra low flush toilet that uses under 2 litres of water per flush. Specific areas of study are water saving potential, hydraulic performance and user acceptability. The study showed that replacing conventional toilets with this type of ultra low flush toilet saved over 80% of water demand in this case. Despite using much lower quantities of water, the reduced flows did not adversely affect drain and sewer function when they are appropriately designed. It was also found that although this type of technology is generally acceptable to users, women by their practice preferred to use a conventional toilet, yet rated the new toilet higher than men.

Palabras clave: Demand management, sewers, ultra low flush toilet, user acceptance, water conservation

1. Introduction

Water management faces a number of key challenges over the coming decades associated with population growth, population migration, changes in demographic structure and climate change. All are placing increased stress on water resources and water delivery. To address these issues, increasing emphasis is being placed on managing demand to conserve or make better us of (potable) water

There are several ways of conserving water in the domestic environment, ranging from changes in user behaviour and use patterns to replacing existing fittings with water-efficient ones. Figure 1 shows the composition of domestic water demand in the UK. The largest component is toilet flushing, which at 30% of the potable water consumed in is arguably an unsustainable practice. It is for this reason that toilets are considered to be the first potential opportunity where water efficiency measures can be introduced (Environment Agency, 2003; Gormley & Campbell, 2006; Inman & Jeffrey, 2006). These measures can be temporary or permanent. The former include adjusting the position of the ball-float (if the toilet type allows it), installing cistern volume adjusters or other devices that can reduce the volume of the cistern, i.e. cistern dams or delayed action inlet valves. Permanent measures consist of retrofitting old toilets with less water consuming devices. Indeed, considerable water and financial savings have been attributed to large scale low flush toilet retrofitting programmes (Green, 2003).

In England and Wales, all toilets installed after the 1st of January 2001 have a maximum flushing capacity of 6 litres (DEFRA, 1999). Many older toilets have cistern capacities of 9 litres or more. Although a number of low flush volume toiletss are emerging, they have not as yet been widely specified. Their uptake is dependent on several factors including cost, functionality and user perception.

This paper examines the performance of a novel, prototype ultra-low flush toilet (ULFT) with respect to water savings, user acceptance and hydraulic performance, as a contribution to managing demand. It is part of a larger project WaND (Water cycle management for new developments: www.wand.uk.net) addressing a wide variety of issues associated with water and its management in cities (Butler *et al.,* 2006).

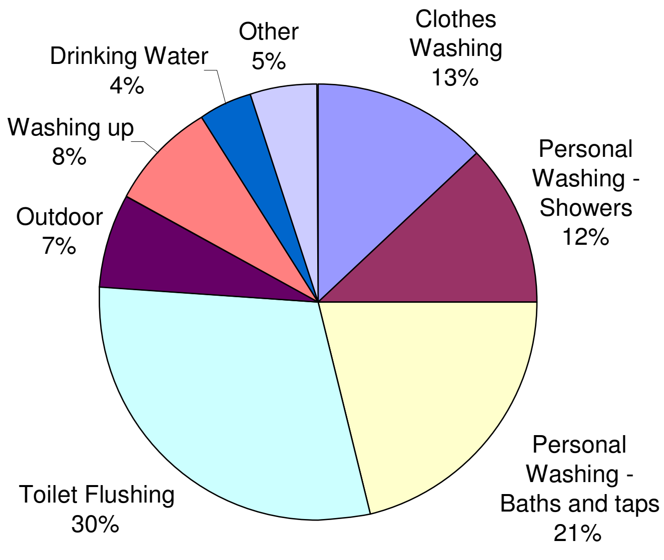

Figure 1. Components of Domestic Water Use (www.waterwise.co.uk)

2. Material and methods

2.1 Ultra-low flush toilet

The device monitored in this study (a propelair® toilet www.propelair.com), uses under 2 litres of water per flush. The ULFT looks like a conventional WC (Figure 1), the only difference being that the lid must be closed before flushing, to create an air seal around the bowl. During a flush, air is forced through the bowl under low pressure. The air acts as the main motive force to expel both the water and waste into the house drain. The flushing process takes about 3 seconds to complete. Once this process is completed, enough water fills the trap to form a water seal. Because it is neither a fully pressurised nor a vacuum system, the ULFT can potentially be installed in the same way as a conventional toilet linked to standard house drains and sewers.

Figure 2. ULFT installed during the trials at WRc. (Photo courtesy of Phoenix Product Development)

2.2 Study

The water savings and user acceptance study took place over an 8 month period (December 2005 – July 2006) at the Water Research Centre (WRc) in Swindon, UK. During this time, a toilet block (see Figure 3)consisting of 5 conventional toilets (2 male and 3 female) was monitored to record water consumption by and usage frequency. The study was divided into two stages: *Stage 1* (two months) and *Stage 2* (six months). The objective of *Stage 1* was to measure background usage of the conventional toilets and to ascertain which two toilets should be retrofitted with an ULFT. The criteria used to choose were "popularity" (determined by the frequency of use) and water consumption (determined by the volume per flush).

Table 1 shows the frequency of use of the toilets (in terms of the number of flushes), and the proportional use in percentage, where F_i and M_i denote whether the toilets are female or male facilities. The table indicates that for the ladies' toilet facilities, popularity was the key factor to select F_3, whilst for the men's, water consumption was the criterion to select M_2. The activities undertaken during *Stage* 2 included establishing users' perception of the ULFT and continuing with the flow monitoring activities in the toilet block that had begun in *Stage 1*. The measurements were undertaken by using *identiflow* loggers to record and monitor water demand, as well as the number of times the toilets were flushed.

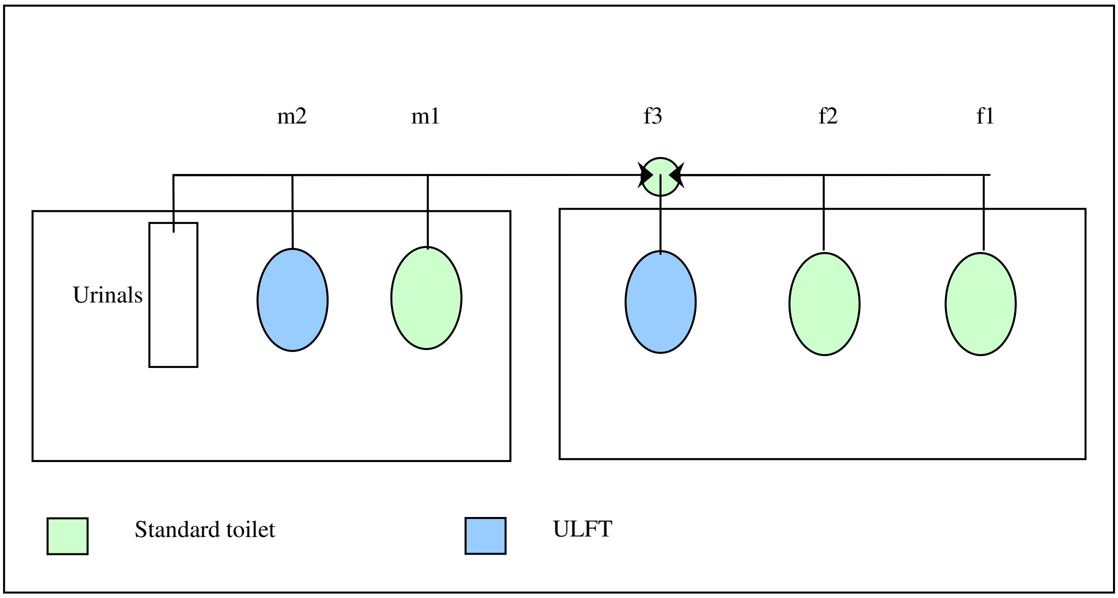

Figure 3. Schematic representation of the layout for the ULFT at WRc

Table 1. Toilet use data obtained with the *identiflow* loggers

Toilet ID	**Frequency of use (no. flushes)**		**Proportional use (%)**	
	Stage 1	*Stage 2*	*Stage 1*	*Stage 2*
F1	277	2147	23	35
F2	58	590	5	10
F3	412	1118	34	18
M1	264	1291	22	21
M2	198	940	16	15

3. Results and discussion

3.1 Water saving potential

The monitoring of the toilet block also provided data to determine the actual volume of water used by the toilets installed (conventional and ULFT). This data is summarized in Table 2 and shows the average volume of water per flush as well as the cumulative volume of water used throughout the trial for toilet flushing. The study found that although the originally fitted toilets had a nominal cistern capacity of 9 litres, the average volume measured ranged between 8.4 litres and 10.4 litres per use (Table 2). The ULFTs registered an average of 1.3 litres, which is slightly lower than their design volume. The information in Table 1 and Table 2 can be used to estimate the water savings potential when retrofitting a conventional (9 l) toilet with an ULFT. In this study, the water savings correspond to 18 cubic metres in a six-month period or a 87% reduction. The ULFTs were flushed a total of 2,058 times during the trial, and no blockage incidents were reported

3.2 User perception

User perception was analysed in two ways: user preference and user acceptance. The former refers to the "popularity" of the ULFT when compared to a conventional toilet, and was measured by comparing the proportional frequency of use of the two types of toilets during *Stage 1* and *Stage 2* of the trials. User acceptance was assessed using questionnaires.

Table 2. Water use for toilet flushing during the trial

Toilet ID	Volume per flush (l)		Total water use (l)	
	Stage 1	*Stage 2*	*Stage 1*	*Stage 2*
F1	8.4	8.6	2341	18532
F2	10.4	9.9	609	5711
F3	10	1.3	4145	1457
M1	8.9	8.5	2375	11566
M2	10.3	1.3	2032	1234

In terms of toilet preference, data obtained from the monitoring of the trial (Table 1) suggests that men showed no particular preference towards either type available (conventional and ULFT), as their use (s a proportion of all toilet uses) was constant throughout the two stages of the trial. Women, instead, seemed to prefer the conventional toilet, as the proportional use of F3 varied between 34% and 18% from Stage 1 to Stage 2, respectively. The latter variation constitutes a drop of 47% in the use of F3. Informal inquiries amongst female users indicate that women may refrain from using the ULFT because of the need to touch the lid to use it. The latter was also one of the concerns expressed by female users of the ULFT via the questionnaire.

User acceptance was assessed by means of short questionnaires designed to be answered by users of the ULFT after their visit to the lavatory. After being answered, the questionnaires were deposited in a box at the entrance of the toilet block. The questionnaires used for this exercise included a brief description of how the ULFT works and instructions for its use (closing the lid before flushing). In addition, they also mentioned that the installed ULFT was a prototype made from resins, and so that the materials in the final version would be different and more robust. The questionnaire consisted of ten multiple-choice questions and a section for comments. The questions were targeted at evaluating issues such as whether the respondent valued water conservation, ease of operation, flushing and cleaning performance, and comfort and design of the toilet.

The size of the sample to assess user acceptance consisted of 57 people (27 men and 30 women) who responded to the questionnaire. Taking into account the total responses (men and women) to the questionnaire, the following can be concluded:

- 81% of the respondents value water a lot;
- 58% thought that the ULFT was obvious and easy to use;
- 93% thought the flushing performance was good;
- 76% thought the cleaning performance was good, and 21% thought that it was adequate.

Results also showed that women value water conservation and rate the ULFT higher than men

In addition to the set of questions, users commented constructively on other aspects of the ULFT:

- Very efficient, would consider buying one for the house when they become available;
- Easy to clean and operate;
- Very quick;
- User acceptability is very important.

Despite these positive comments, users also expressed concerns related to the operation and effects of the ULFT, such as:

- Not being able to recognise when the lid is properly closed, thus not knowing if the flushing mechanism would work;
- The need to close the lid is seen as unhygienic or difficult for children/disabled people;
- The possibility of having blocked drains due to the reduced flush volume.

From the data obtained, it appears that in *general* the ULFT can be thought of as being an acceptable alternative to the conventional toilet. Users were pleased with its performance in terms of flushing and clearing waste, possibly two of the greatest concerns considering the low-volume of water used. In addition, another factor that might have contributed to user acceptance is the fact that, due to the location of the prototype toilets, people who tried the ULFT would be involved in one way or another with water management activities (81% of respondents valued water conservation *a lot*).

3.3 Effect on drains and local sewers

One of the concerns expressed in the user study was the potential for the new toilets to cause drain blockage. This is indeed a valid point as reduced flows, due to the widespread introduction of low flush toilets, has the potential to alter hydraulic regime and slow down or impair the movement of gross solids in small sewers in particular.

The characteristics of the movement of gross solids in small bore pipes has been investigated and reported for a number of years (Littlewood, 2000; Littlewood & Butler 2003; Butler et al., 2005a,b; Littlewood *et.al.*, 2006). In addition to the water saving and user perception study, a parallel investigation was conducted to compare the ULFT's hydraulic performance with that of a 6/4 litres dual-flush WC. The laboratory tests took place in a purpose-built rig at WRc (Figure 4). The rig consists of a 25 m long flume with variable gradient. The flume can be configured to represent various pipe-toilet arrangements. For this particular study, various pipe diameters (50 mm, 75 mm and 100 mm) and materials (Perspex, flexible pipe) were used to represent different installation possibilities. The toilets were connected to the upstream end, and the gradient was kept constant at 1%.

The comparison criterion used to assess the performance of two types of toilet was the *limiting solids transport distance (LSTD).* The LSTD can be defined as the maximum distance a solid (of given characteristics) can travel for a particular flush, gradient and pipe diameter combination. A solid is considered to reach its LSTD when it remains stationary after three consecutive flushes (Littlewood & Butler, 2003). The laboratory tests consisted of flushing an artificial solid down the pan of a toilet and recording the distance travelled with each flush. The experiments were repeated five times for each solid-pipe-WC combination, to ensure repeatability. The results obtained for the ULFT and the conventional dual-flush toilet are depicted in Figure 5. Results show that the performance of the ULFT, is comparable to a standard 4 litre flush in a 75 mm pipe and when connected to a 50 mm pipe, is superior to that of a conventional toilet using 6 litres.

Figure 5 also shows that the pipe diameter plays an important role in solids' transport, when using the ULFT: the smaller the diameter, the greater the LSTD. This finding can be used to establish design guidelines for the installation of ULFTs, by using the LSTD as a measure of maximum distance between the ULFT and other sources of flow. The latter includes kitchen appliances and flows deriving from baths and basins. If this is not possible, then the LSTD could be used (in conjunction with a safety factor) to connect the ULFT to the main domestic drain. Another possibility presents when several toilets are installed together as a block (i.e. public toilets) where the flushes should augment each other. During the 6 month trial, there were no reports of blockages or problems with the local drains.

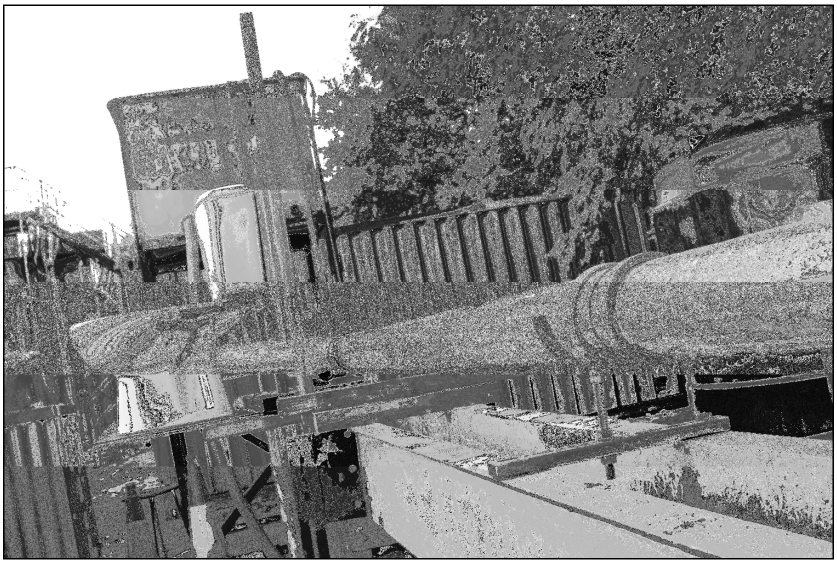

Figure 4. Upstream end of the test rig, showing a conventional toilet connected to 100mm diameter pipe

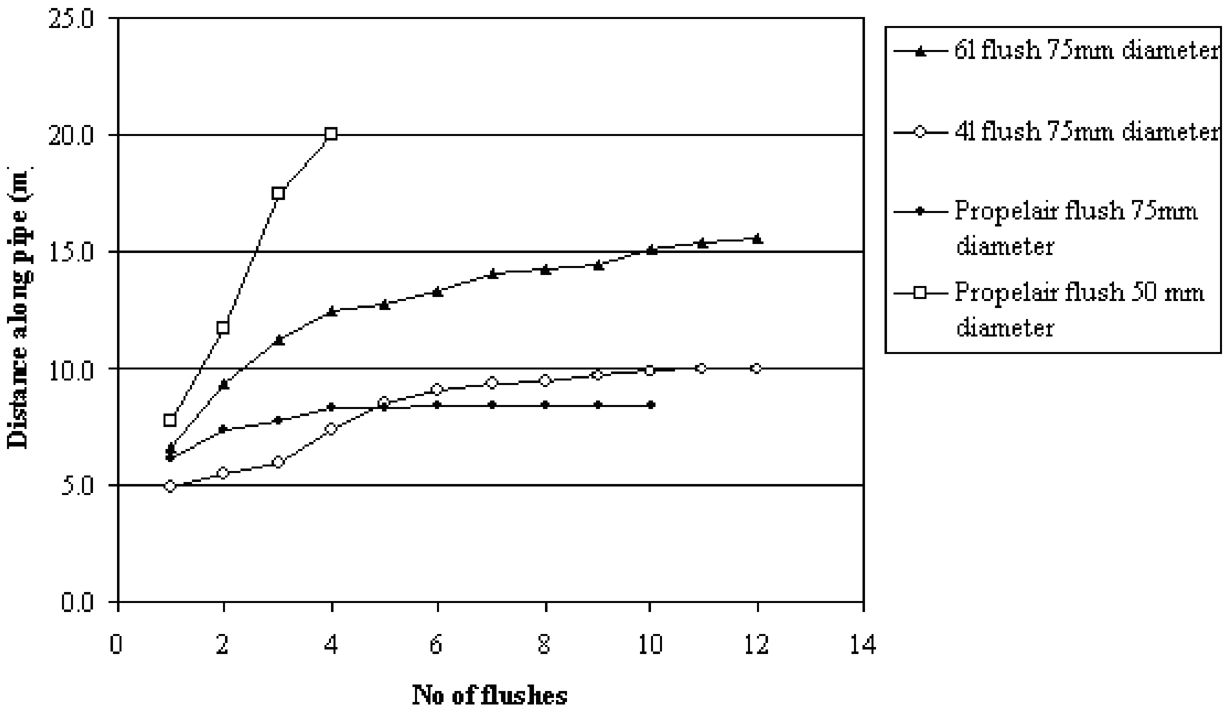

Figure 5. Limited solids transport distance of ULFT and conventional toilets

4. Conclusions

The replacement of conventional toilets with systems designed to use less than 2 litres per flush appears a feasible and rewarding option. Over the period of the trial some 18m^3 of water was saved by replacing just two 9 l flush toilets, a saving of 87%. In the trials, there were no reported instances of drain blockage.

This study found that, in general, the proposed ULFT was accepted by the user group. Users were satisfied with its flushing and cleaning performance. They were also pleased with its design and level of comfort. However, the users in this case were relatively well-informed individuals and may not have been representative of the public in general. Interestingly, however, although women were generally enthusiastic about the product (compared to men), they did have some concerns about using it and actual use of that particular toilet showed a drop-off after it was retrofitted.

One of the main concerns expressed was the relationship between reduced flows and the possibility of blockages occurring. The latter issue was addressed by means of full scale laboratory based experiments, which indicated that when installed using a 50 mm pipe, results from laboratory tests show that the ULFT performs better than a standard toilet that uses 6 litres of water per flush.

5. Acknowledgements

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