Opportunities for more efficient toilets in Australia - How low can we go?

Simon Fane and Anna Schlunke
Institute for Sustainable Futures, University of Technology, Sydney

Abstract

Toilet flushing represents a significant fraction of the total water supplied to Australian cities and towns. This proportion only increases when water restrictions are in force. Toilets in Australia are however already relatively water-efficient. The average flush volume of a toilet sold today is about 50% of what it was 25 years ago and low flush 4.5/3 L models are now widely available.

This paper draws on the outcomes of a study for The Australian Government Department of the Environment, Water, Heritage and the Arts. The study assessed the opportunities for introducing more efficient flush toilet classes into Australia. Both the study and this paper address flush toilets solely and exclude the issues and opportunities associated with vacuum and dry toilets.

As part of the study, interviews with stakeholders were used to identify possible issues around the introduction of more efficient toilets. While many stakeholders expressed enthusiasm for the prospect of saving water through greater toilet efficiencies, commonly raised concerns included the ability of the flush to effectively clear waste from the pan, drain line carriage, and the impact of lower flows on the sewer system in general. On the regulatory side it was noted that, as it stands, the Australian Standard for toilet Cisterns (AS 1172.2) effectively bar the introduction of more efficient toilets than current 4.5/3L models.

Significant water savings are possible with toilet classes currently common in some overseas countries. In the short term, however, the largest hurdle for parties considering introducing such toilets into the Australian market will be convincing Standards Australia Committees that toilet performance is adequate for Australian conditions. This is likely to be difficult without conducting extensive Australian field trials. In the medium term a number of proposed studies, in various Australian contexts, on what the limits are in terms of minimum flush volume have the potential to better define the necessary performance characteristics and may facilitate the introduction of novel low flush classes.

1. Introduction

At least 25% of indoor residential water use is due to toilet flushing and as a proportion this water use increases in drought situations when water restrictions are in place. In the context of many cities and towns in Australia facing increasing water scarcity, all opportunities for increasing the water efficiency of toilets across the country are worth investigating.

The Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) commissioned the Institute for Sustainable Futures (University of Technology, Sydney) to assess the opportunities for more water-efficient toilets. Specifically the study addressed the potential for introducing more efficient flush toilet classes into Australia than the current low flush 4.5/3L models. The investigation involved interviewing key stakeholders, modelling possible water savings, analysed the likely technical, regulatory, or standards related barriers and proposed possible solutions to these problems.

This paper draws on the outcomes of that study but the paper's scope is limited to:

- What more water efficient toilet classes exist than current 4.5/3 Litre models?
- What are the key regulatory factors limiting the introduction of more efficient toilet into Australia? and;
- What technical factors will need to be considered if more efficient toilet models are to be introduced?

The full study report including results of modelling water savings outcomes, analysis of cost effectiveness, and direct stakeholder quotes can be found in the report titled " *Analysis of Australian opportunities for more efficient toilets* " published on the Department's www.waterrating.gov.au web site.

1.1. A brief history of water-efficient toilets in Australia

Since the introduction of dual flush toilets in the 1980's the water efficiency of toilets in Australia has increased significantly and the introduction of each new class of toilet has seen a progressive reduction in average flush volume (Snelling *et al.* 2007).

Up until 1982, all toilets in Australia were single flush models. The average flush volume of these toilets was about eleven litres. Dual flush toilets were initially introduced with an 11/5L configuration. In 1989 the 9/4.5L model was introduced. Shortly after 1989 these 9/4.5L toilets where made mandatory. This was only after extensive trials including retrofitting a number of whole communities.

In 1995, again after extensive field testing by Caroma (now GWA Caroma), the 6/3L class was introduced. More recently, in 2005, the 4.5/3L class was introduced, again after field trials by GWA Caroma, which tested their model in this class.

1.2. The WELS scheme for toilets

The DEWHA administers the Australian Government's Water Efficiency Labelling and Standards (WELS) Scheme. Since 2006 the Scheme has required toilets and other water using fixtures/appliances to display a WELS water-rating label at the point of sale. The label shows a one to six star rating, allowing a comparative assessment of the model's water efficiency. Average flush volumes for star ratings are shown in Table 1.

Table 1 WELS star ratings for toilets

Star rating	Average flush volume*	Toilet classes with this rating in WELS data base
1	Not more than 5.5 L	9/4.5L dual flush, 6L single flush**
2	Not more than 4.5 L	*No models available*
3	Not more than 4.0 L	6/3L dual flush, 4L single flush
4	Not more than 3.5 L	4.5/3L dual flush
5	Not more than 3.0 L	4.5/3L dual flush with integrated hand-basin***
6	Not more than 2.5 L	*No models available*

*Average consumption of a dual flush toilet is taken as one full flush and four half flushes.

** These represent 6L single flush models with the flush volumes adjusted down to 5.5L

*** The average flush volume is 3.5 however grey water reuse within the cistern allows the lower flush volume to be claimed

As table 1 shows, excluding innovative hand basin reuse models, no 5 or 6 star toilets are available. As well as the star ratings, the WELS Scheme also includes a minimum standard for water efficiency for toilets. This requires that the average flush of toilets sold in Australia must not exceed 5.5 litres.

The Australian standard for WELS (AS 6400) acts to codify the WELS Scheme.

2. Water efficient toilet classes found in Australia and Internationally

So, other than low flush 4.5/3L models already commonly available in Australia, what more efficient flush toilet classes exist?

2.1. 4/2L dual flush toilets

Internationally the markets for what are considered 'low flush' toilets vary considerably and, compared to many countries, Australian toilet classes would be considered as highly efficient. In several markets in Europe, however, dual flush 4/2L toilets are not uncommon. Several models of toilet exist in this class.

At least one European manufacturer expressed the desire of introducing their 4/2L model into the Australian market. This process has been unsuccessful to date, as this class of toilet is not currently eligible for registration in Australia (see section 3 below).

A dual flush 4/2L toilet would have a nominal average flush volume of 2.4 litres. This would give these toilets a WELS star rating of 6 stars. In testing, however, a 4/2L toilet model by Ifo's Cera reported a full flush volume of 4 litres and 2.4 litres reduced flush. This model would achieve a 5 star WELS rating, if it could be registered in Australia.

2.2. 3/2L and 2/1L litre dual flush toilets

In Scandinavia, 3/2L dual flush toilets have been in use for some time. These toilets are, however, generally installed in holiday homes with rainwater tanks and limited water supplies. These situations commonly involve steeper than average drainage grades.

A dual flush 3/2L toilet would have a nominal average flush volume of 2.2 litres which would translate into a WELS star rating of 6 stars.

2.3. Dual flush toilets with integrated hand basin

Integrated hand basin grey water reuse models reduce water consumption by using the same water for two purposes: hand washing and toilet flushing. A tap and hand basin sit atop the toilet cistern and potable water used to wash the user's hands then passes into the cistern for use in flushing.

In this class, Caroma has developed the Profile™ toilet suite which is a 4.5/3L dual flush toilet with a hand basin integrated. In the Profile™ model the tap flows when the toilet is flushed and because of the water reuse feature the Profile™ obtains a 5 star rating under WELS. Also in this class, Oz-Aquasaver has also developed a retrofit cistern that can be fitted on to an existing pan.

2.4. Urine separating toilets

Urine separating or urine diverting toilets have two bowls within the one pan to collect the faeces and urine separately. This also allows very low flush volumes for the reduced or urine flush when compared to the full flush. The reduced flush volume for a urine separating toilet is usually around 0.2 litre per flush. Full flush volumes for urine diverters are commonly between 4 and 6 litres per flush. The result is an average flush volume of between 1 and 1.4 litres which is significantly lower that the criteria for a 6 star WELS rating. Achieving average flush volumes would however require behaviour change from both male and female toilet users (sitting down is generally required and paper cannot be flushed along with urine).

By 1999, about 3000 urine diverting toilets had been installed in Sweden (Hellström and Johansson, 1999). More recently, two municipalities (Tanum and Norrköping) have mandated urine diverting toilets in new and renovated bathrooms (Cordell, 2006).

In addition to low flush volumes, urine separating toilets could also give the additional benefits in terms of recycling nutrients via the capture and use. This is because the urine (with its high phosphorous and nitrogen content) can be stored and utilised as fertiliser.

2.5. Air assisted flush toilets

Propelair is a UK-based company which has designed a new type of toilet with an air assisted flush. Because of the pressurised air assistance, the flush volume is about 1.5

litres (significantly lower that the criteria for a 6 star WELS rating). The toilet is at pre-production stage with in-situ trials completed in the UK.

Users of this toilet are required to close the lid before flushing thereby forming an air seal. A small amount of water is then passed into the bowl to wash it, followed by displaced air. This air displaces the contents of the bowl and water is reintroduced to replenish the water trap seal (Propelair, 2007). The toilet's appearance is similar to a standard toilet and it can be connected to existing drainage systems.

The air displacement requires a small electric motor and it should be noted that air assisted flush toilets therefore differ from pressure assisted toilets.

Testing of the Propelair model has been conducted by the Water Research Centre in the UK. The tests were against the European Standard which incorporates tests that are also required by the Australian Standard AS1172. The testing revealed low average flush volumes, reduced net energy use (once the embodied energy in the water was accounted for) and good user acceptance (Waylen, 2007). The company indicates that they have plans for trials in Australia (Propelair, 2007).

3. Regulatory barriers to more efficient toilet

To receive a star rating under WELS toilets must meet the criteria against which water use efficiency is rated and also comply with the Australian standards for flush toilet (AS 1172.1 and AS 1172.2) or relevant Australian Technical Standards for flushing valves and solenoid valves (ATS 5200.020, 5200.021, 5200.030).

To comply with the Australian Standards, toilet models must be included in Table 4.1 of the Australian Standard for Cisterns (AS 1172.2). This table gives the acceptable range of average flush volume for different toilet models. The classes included in the Standard are:

- Single flush toilets – 6 L and 4 L.
- Dual flush toilets – 6/3L and 4.5/3L.
- Replacement cisterns to match pre-installed pans only – 9/4.5L.

The range of acceptable flush volumes for 4.5/3L toilets, which are the most efficient toilets included in Table 4.1 of AS 1172.2, is 3.1-3.5 litres per flush. It is therefore not possible to have a 6 star WELS rating toilet as to receive the 6 star rating toilets must have an average flush volume of no more than 2.5 litres. Further, only the integrated hand basin models that reuse grey water within the cistern of a 4.5/3L dual flush model can be registered with a five star WELS rating.

As most five or six star WELS rated toilets do not currently comply with the requirements of the Australian Standards for flushing toilets they cannot be registered for WELS. Consequently they can not be supplied in Australia.

As it remains sensible to link the WELS and toilet Australian Standards, any changes that allow the introduction of more efficient toilet classes into the Australian market will need to be made in the Australian Standards for toilets (AS 1172.1 and AS 1172.2)

4. TECHNICAL CONCERNS

This section utilises information from stakeholder interviews to draw attention to the technical issues that arise due to decreasing the volume of flush water. These technical issues range from the level of the toilet suite itself, to the level of the house or building, to the wider sewer network and waste water system to which the toilet will be connected.

4.1. Toilet performance

It was evident from stakeholder interviews that all aspects of toilet performance need to be considered, not just its water efficiency.

Firstly, for a toilet to be truly water efficient, it has to function properly. If it does not flush properly the first time, then it is not water efficient. A key to this is the issue of amenity of the toilet pan for the user. Designing toilets for increased water efficiency without maintaining the performance of the flush can lead to the pan being left more frequently marked, which may result in multiple flushing or frequent manual cleaning.

A number of interviewees also indicated that, in their experience, drain line carriage was not dependent solely on flush volume but also that toilet performance and design had a significant effect. One example given was when a 6/3L toilet had a tendency to block, but when it was replaced by a 4.5/3L toilet there were no more blockages.

4.2. Drain carriage

It is critical that toilet flushing not only clears waste from the pan, but also transports the waste through the drain to the main sewer line.

The most commonly mentioned technical barrier to introducing more efficient toilet classes into Australia was drain line carriage. The overall message was that the performance of the whole household or building plumbing system needs to be considered, not just the toilet. When there are problems with the plumbing, the toilet is often allocated the blame but the problem may really be the drain line.

Blockages in the drain line joining the outlet of the toilet to the main sewer line can be caused by a number of things. Pipe work can be damaged over time, develop cracks or be invaded by tree roots. Older houses may have terracotta pipes in their plumbing systems. Some plumbing systems use right angle connectors (rather than at a smaller angle, which would reduce the chance of waste flowing the wrong way). These systems may all function properly when the volume of water flowing through them is high, but if the volume is reduced through the use of more efficient fittings and appliances, then problems can start to emerge.

When efficient toilets are positioned on a drain line with no upstream flows, or one that is not used frequently, blockages can also occur. It was mentioned that some builders are experiencing such blockages in the pipe work connected to three and four star rated toilets.

Reduction of the flow in drain lines will also be caused if there is separation of grey water plumbing within the home to allow collection and reuse. In Western Australia the Department of Housing and Works introduced a minimum standard of 4 stars for toilet

suites in September 2007, as part of the 5 Star Plus Housing Scheme. As part of Stage 2 of that scheme, which will start in 2008, new homes on suitable lots must be plumbed to enable grey water diversion to allow grey water reuse systems to be introduced at a later time. Due to concerns that were raised about the effect that the combination of efficient toilets and grey water diversion will have on drainage systems, the Master Plumbers and Gasfitters Association has begun coordinating a number of trials in order to monitor the performance of drainage systems when the grey water is diverted.

4.3. Reduced flows in sewer network

Some people raised potential concerns about flows in the main sewer line as well as the in house or in building drainage and queried 'Would more efficient toilets cause sewer carriage or waste water treatment problems?'.

Others believed that it may become a problem as flows continue to decrease or could possibly emerge as a problem in areas on the edge of the existing system, where all houses are highly water-efficient.

If more efficient toilets did lead to more sewer blockages this would be a concern as blockages cause septic sewers, leading to odour and corrosion problems through sewerage networks. However the proportional decrease in sewer flows due to more efficient toilet model are unlikely to cause such impacts.

4.4. What are the potential solutions?

Study "how low can we go?"

Various interviewees indicated that there is a need to better investigate the interaction of very low-flush toilets with drainage systems in the Australian context. To date there has been no systematic study on this in Australia, but internationally there has been some research. McDougall and Wakelin (2007) investigated the effect of flush volume, drainline slope, drain diameter, drain shape (circular or non-circular) and the length of the drain on the performance of the combined toilet and drainline. The ability of a single toilet to transport waste solids to the first pipe junction was analysed. Flush volumes of 9.1L to 4.5L were investigated. By extrapolating the data trends, McDougall and Wakelin suggested that average flush volumes below 4 litres would be feasible if the system and appliance design parameters are considered.

By incrementally reducing toilet flush volumes and studying the impact on the whole system, it should be possible to gauge how low flush volumes can go before carriage becomes a problem.

Jeff Clark from SA Water is chairman of a working group that is organizing such a study. The study will explore what the limits are in terms of minimizing flush volumes with existing systems. It will also investigate the effect of combining low flush toilets with grey water reuse. In the proposed study the flush volume will be decreased incrementally and the performance of toilets monitored.

By studying toilets as part of the drainage system, the positioning of toilets could also be considered, and translated into advice on installation (for example, in new buildings there should be other fixtures such as baths or showers upstream from toilets).

Alternative technologies

Air assisted flush toilets (Propelair for example) may be a solution to some drain line carriage issues. Although vacuum toilets were not included in the scope of this study, it was mentioned by a number of interviewees that these are proven, commercialised, low water use (1 litre per flush) options that avoid the drain line carriage issues that higher efficiency traditional flush toilets may cause. It was also suggested that composting and waterless toilets (also not part of the scope of this study) could be an alternative to higher efficiency flush toilets.

Small bore sewer or STEP (septic tank effluent pump) systems are another alternative. With these systems, sewage from homes or buildings goes straight to a local septic tank were solids are retained. The liquid fraction of the effluent is then pumped to a usually decentralised waste water treatment plant. Sewer carriage is therefore removed as an issue. As with all septic tanks, STEP tanks must be pumped out periodically to remove accumulated solids (sludge).

Use of alternative water sources

Grey water from the hand basin is already used for flushing five star toilet models. Other sources of alternative water supply for toilet flushing were also suggested.

Education and changed behaviour

It was suggested by various stakeholders that behavioural change could solve some of the toilet blockage problems. Particular areas identified were the use of excessively thick toilet paper, what was flushed down toilets and that if a house has many toilets they should all be used (or are perhaps not all toilets are needed).

5. CONCLUSIONS AND RECOMMENDATIONS

Analysis has shown that there is a significant potential to cost effectively save water through the introduction of more efficient toilets into the Australia (Schlunke *et al* 2008). Despite this potential an overarching theme in conversations with stakeholders was that for a toilet to be truly efficient, it must not only have a low flush volume, it must also work properly. This means that all aspects of a toilets performance need to be considered, not solely carriage but also user interactions, including aesthetics.

A second theme in of many conversations with stakeholders was the need to take a ‘systems’ perspective on the operation of low flush toilets. This means extending the consideration beyond the cistern and pan and considering the issue of the drain line configuration and also taking into account the user and ancillary factors (e.g. paper use, paper type).

It is significant that all the more efficient toilet classes identified and considered in this study would require at least minor behaviour change from a proportion of users if water savings are to be maximised. Introducing certain new toilet classes would also require a change in practice from plumbers.

Drain and sewer carriage were raised as possible issues by many stakeholders. However, carriage is affected as much by wastewater flows from other fixtures as the toilet flush volume. The proposed study by Jeff Clark from SA Water that will explore what the limits are in terms of minimising flush volumes could provide useful data on this issue.

The way the toilet market moves forward in terms of water efficiency over the next five to ten years is likely to be affected by the outcome of such studies. If the results of this and other studies suggest that lower flush volumes are possible then this will assist the market move towards lower water use models.

A number of recommendations arose out of the full study into opportunities for more efficient toilets. The Four most relevant to this paper were:

- To facilitate the introduction of more efficient flush toilets, the Australian Standards for toilets and their installation should look at moving towards a 'systems approach'. This would mean that certain types of toilets could only be installed in certain situations, with their installation meeting particular criteria on drain line slope and length. It might also involve specifying different requirements for various types of very low flush toilets and reflecting these within both the technical standards and the plumbing standards.

- That the WS-032 and WS-003 Standards committees consider changing the structure of the toilet standards to include technical based maximum, minimum and average flush volumes for toilets, so that rather than including toilets according to class, they are included according to a greater number of more specific performance criteria (as occurs in many international toilet related Standards).

- That Federal Government provides grants or partial funding of studies of what the limits are in terms of minimising flush volumes for toilets, and for trials of new classes of water saving equipment (including toilets) in Australia.

- That documentation be developed of what was done in the past to add new toilet models to the toilet standard (and any other relevant standards changes that were made). Details should be given on the way trials were conducted.

It was also recommended that a new study address the question of opportunities and barriers to alternative toilet technologies (dry and composting toilets and vacuum systems). It is possible, particularly in the mid to long term, that these may become a more significant component of the toilet market in Australia. As non-renewable resources are depleted globally it is possible that moves to nutrient capture and reuse may drive such as change.

REFERENCES

AS/NZS 6400:2005: *Water efficient products-Rating and labelling*

AS 1172.1-2005: *Water closets (WC) – Pans*

AS 1172.2-1999: *Water closet pans of 6/3 L capacity or proven equivalent – Cisterns*

ATS 5200.020-2004: *Technical Specification for plumbing and drainage products - Flushing valves for water closets and urinals - for use with mains supply*

ATS 5200.021-2004: *Technical Specification for plumbing and drainage products - Flushing valves for water closets and urinals - for use with break tank supply*

ATS 5200.030: Technical Specification for plumbing and drainage products - Solenoid valves

Australian Government (2007) Water Efficiency Labelling Scheme (WELS). Accessed online October 2007 at: http://search.waterrating.com.au

Caroma (2007) Web site accessed online October 2007 at: http://www.coroma.com.au

Cordell, D. (2006) Urine Diversion and Reuse in Australia: A homeless paradigm or sustainable solution for the future? Linköping University: Sweden

Hellström D., Johansson E. Swedish experiences of urine separating systems (Schwedische Erfahrungen mit urin-separierenden Systemen; in English). Schwerpunkt "Moderne Sanitärkonzepte"). Wasser und Boden 1999; 11/26, Jahresinhaltsverzeichnis 51.

McDougall, J.A. and Wakelin, R.H.M., The influence of flush volume and branch drain cross-section on deformable solid transport in attenuating flows, Building Services Engineering Research and Technology, 28,1 (2007) pp. 7-22.

Propelair (2007) Accessed online November 2007 at: www.propelair.com

Schlunke, A. Lewis J. & Fane, S, 2008, *Analysis of Australian opportunities for more efficient toilets*, [prepared for the Australian Government Department of the Environment, Water, Heritage and the Arts], Institute for Sustainable Futures, University of Technology, Sydney, February.

Snelling, C., Turner, A., Riedy, C. White, S. and Cummings, S. 2007 'Where does the water go? Best practice stock modelling for water using appliances' *IWA Efficient 2007*,

SwedEnviro (2001) Market survey – Extremely low flush toilets. SwedEnviro Report No. 2001:1

Waylen, C. (2007) Briefing note on Propelair trial. Water Research Centre: UK