Water Efficiency, Domestic Appliances and Hydraulic Design for On-site Systems

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Abstract

The generation of wastewater in a domestic residence depends not only on the vigilance of the residents in their daily water use habits but also on the capacity of domestic appliances to minimise water use. We, as consumers of potable water, are often bombarded with the advertising directed at consumers of water from metropolitan water supplies. As reserves dwindle away during drought, the advertising becomes more intense and often comes too late in the overall water management strategy. As consumers of water we generate wastewater that has to be dispersed on the land on the same lot on which we have many of our other living requirements, water use reduction often becomes a permanent necessity. Too often, though, the water using appliances in the home have been installed to meet plumbing codes and the perception that each appliance can be operated independently of other appliances in the house.

Government incentives for residents to change shower roses, replace toilets with dual flush cisterns, install front-loading washing machines and fix dripping taps are often poorly conceived strategies, expensive and counter-productive.

This paper examines the differences in water use that can be gained from a detailed restructure of the domestic plumbing practice and a wise use of water conserving appliances. The fallacies of retro-fitting dual flush toilets, the practical differences between front-loading and top-loading washing machines, the technological advances in dishwashing and the ideals of an acceptable shower rose are explored.

Keywords

domestic appliances, dishwashers, dual-flush toilets, washing machines, wastewater, water conservation,

INTRODUCTION

In the wake of the current low levels of water in metropolitan storages (Brennan & Patterson, in press) there is a concerted political shift to encourage water reuse, recycling and reduce consumption. All the current restrictions in most metropolitan areas and larger regional cities are based upon enforcement of external water uses including landscape irrigation, washing cars from hoses, hosing paths and buildings and filling swimming pools. Perhaps because of the difficulty of enforcement, no restrictions apply to internal water use even though internal use may be 50% to 70% of the total household consumption Expectations of changes in behaviour may come slowly in communities that expect water on demand and have for decades received water at a very low price.

Seventy-five percent of the population of NSW lives in 2.5% of the land area (EPA,2003) increasing at 1% p.a., while the rest of the state increases by only 0.4% and the inland population is projected to fall.

Sydney's water consumption has grown to 106% of the yield of the catchments (EPA, 2003) and the current situation of extravagant water use, both internally and externally, cannot continue. For those dwellings relying solely on rainwater or dependent upon on-site treatment, a low water use psyche is a matter of conserving a limited resource.

Sydney Water (2002) estimates that a savings of 20 kL per year can be achieved for an average Sydney household by the installation of devices such as low-flow shower heads, water efficient appliances and some changes in behaviour. At the current price of water in Sydney ($0.98/kL) this saving amounts to $20 in a normal year. The community needs these water savings for the security of the reservoirs. The cost to the individual may be irrelevant in the short-term.

The Australian Consumers' Association (ACA) (2003) have used examples to show how opposing behaviour in two households, the conservative household can save $400 per year. This is a poor example because the average household water bill is less than $325 (DLWC, 2001). It appears there are many misconceived ideas as to how much water the more efficient devices can achieve and how much the average household uses.

In the estimated 234,000 households that have on-site systems in NSW (Brennan & Patterson, in press), water conservation plays an important role in addressing security of supply, as well as minimizing the area of land required to apply the hydraulic load.

This paper examines only the potential water efficiency of internal water use and the considerations that are implicit in water conservation in a single household. These considerations apply equally to houses that discharge wastewater to sewer or houses that rely upon on-site treatment and land application of effluent. The issues of greywater recycling or reuse are not addressed here.

Generation of wastewater

It is unfortunate that there are no reasonable statistics of metropolitan or urban residential water use when each of the water authorities meters every connection at least six-monthly for charging purposes. There are no reliable data on the use of water by households in Sydney. Sydney Water (2001) reported that per capita water use is 427 L/day '*calculated by dividing the total volume of water supplied over the year by the average total population in the supply area for that year*'. Such an estimate is seriously flawed because it accounts for industry and commerce as well as tourist and fire services in the total water consumption.

At an occupancy of 2.7 persons per household (ABS, 2003), the estimated daily water use is 1153 L/day. The EPA (2003) breaks down customer groups to show that houses, flats and units consume 71% of the annual volume of Sydney's water, and outdoor use is about 25%. Applying those proportions to the household rate of 1153 L/day, the internal use is calculated at 614 L/day compared with 586 Lpd stated by Sydney Water (2003b). The inconsistencies continue, and without accurate data, calculations of reduced water consumption or hydraulic load are semantic.

In a press release dated August 2003, Sydney Water (2003) tabulated the water consumption for single dwellings by local government areas (LGA). These data have been further analysed and are presented in Figure 1 showing the number of single dwellings in each of 45 LGAs represented as a proportion of the single dwellings relative to the total number of single dwellings. Figure 2 shows the average household consumption based upon postcode. There is no obvious trend although there is some clustering around 800 L/day but there are extremes in both directions.

Water Pressure

Town water systems are designed to provide minimum flow to each residence of 12 L/s and in such a way that one service does not detract from others on the same main. At sites in Armidale water pressure has been measured at 66 m head, sufficiently high to wear holes in taps around the washers and cause minor misclosures to become severe leaks. Pressure limiting devices can be fitted at the point of water entry into the house, or at specific fittings within the house. Pressure should be rated higher in water conservation strategies because it is simple to remedy and reduces hydraulic load.

NATIONAL WATER CONSERVATION STRATEGY

The National Water Conservation Rating and Labelling Scheme is administered by Water Services Association of Australia (WSAA). The scheme covers shower heads (122 records), dishwashers (141), clothes washing machines (91 front-loaders, 18 top-loaders), taps and tap outlets (77), toilet suites (82) and flow regulators (246). The voluntary scheme aims to certify devices that conserve water without the difficult task of having to change behavioural habits (WSAA, 2003). Certified products comply with *AS/NZS 6400 Water efficient products – Rating and labelling*. It is unclear as to whether WSAA has any authority to certify.

George Wilkenfeld and Associates (GWA) (2003) stated that the voluntary code is neither widely recognised nor clearly understood by consumers. The scheme has worked effectively as a voluntary label but lacks some of the elements required as a mandatory comparative label. They also suggest that despite being a comparative labelling program it has developed some of the attributes of an endorsement label, which assists water utilities and their customers to identify models for rebate purposes, rather than a purely comparative label (GWA, 2003). A brief inspection of the WSAA website will reveal that there is insufficient information available for the consumer to make an informed choice other than one based on water rating. Water efficiency is only part of any selection criteria when purchasing a new or replacement device, price being a significantly high priority in most households.

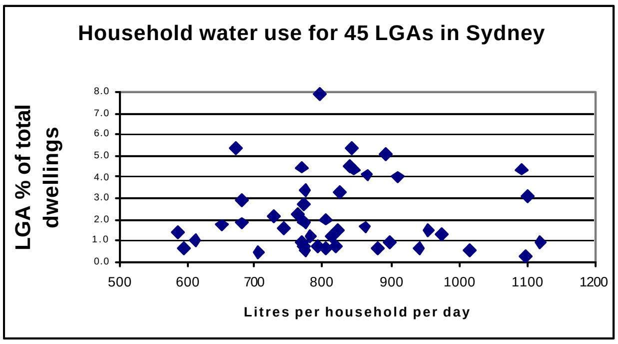

Figure 1 Household water use by LGA

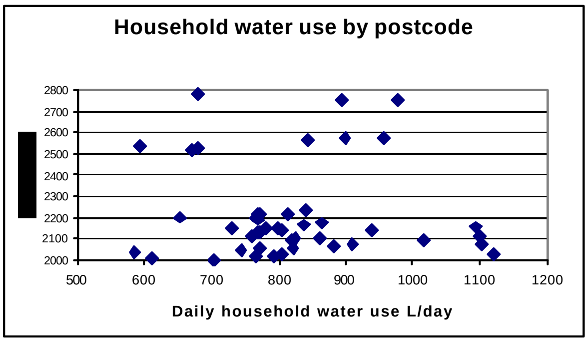

Figure 2 Household water use by LGA

The Sydney Water website, which links to the national labelling scheme, lists the models of shower heads that are subsidized under their incentive scheme and provides additional information for the consumer to assess the merits and compare between brands. Comparisons of washing machines and dishwashers conducted by the ACA, while limited to current models, do address performance as well as price and serviceability. The ACA website has a user-friendly comparison facility.

WATER EFFICIENCY

The notion of water efficiency may be one that conjures thoughts of water reduction for no effort and no change in lifestyle. Advertising ploys link "environmental benefits' to appliances that have more AAAs than a competitor's product and so command a higher price.

For water authorities the imperatives of water conservation are also related to difficulties in gaining approval for the construction of new dams, not because of the economic cost or social requirements but the environmental approvals. The emphasis on water efficiency rather than considerations of energy efficiency may be shifting the state's problems from water to electricity generation.

For the individual there may be incentives for saving money, although at the higher end of the socio-economic scale predicted savings are hardly inducements, while for the lower socio-economic group the cost of the changes to water efficient appliances are probably well beyond the budget. Some savings in water are also transferred to savings in energy, such as a front-loading washing machine requires less energy to heat the water than a top-loader simply because there is less water to heat. Similarly savings by reducing water used in a shower, reduces both cold and hot water, saving in both water and energy.

The increasing demand for water in Sydney is coaxing the manufacturers to design and market efficient products. The nearly two million homes in Sydney will always be a market dictator compared with the quarter of a million homes with on-site systems. The EPA (2003) estimates that the savings in the last two years have come from retro-fitting 180,000 households with more efficient water devices, saving an average of 20 kL per household per year. However, when Sydney Water's supply network leaks more than 86,000 ML per year (Sydney Water, 2001) the potential savings by all households at 20 kL per year is 40,000 ML per year. The difference in the cost of saving water is shifted from the water authority (fixing leaks) to individuals purchasing items to reduce water consumption.

Water saving tips

The proliferation of information leaflets, advertisements in the media (radio, television, newspapers and magazine) and the use of sporting identities to push a particular theme is becoming an industry to itself. The notion that a large proportion of the community, bred on water that has been a poorly valued commodity, will alter its behaviour because of these promotions may be less effective than using real market pricing.

Any water conservation strategy has two components; the non-monetary savings comes with changing behaviour; and that brought about by changing items, fixtures and devices. The lower socio-economic groups will be disadvantaged by the latter, while the higher socio-economic groups will remain unmoved by pleas to save water irrespective of the impact the installation of water efficient devices would have on disposable income.

An important consideration is that the replacement of old inefficient devices with the latest technology is one of financial priority. Many appliances such as toilet cisterns, taps and kitchen sinks have serviceable lives of more than fifty years and unless a room is being renovated it is unlikely that the homeowners will replace an expensive item to save a few dollars. Washing machines and dishwashers have serviceable lives of 10-15 years and are usually only replaced at the end of their serviceable life.

Strategies that produce reasonable cumulative water efficiencies are often the simple tasks such as fixing leaks, checking for over-night leaks by monitoring the water meter. The behavioural changes include turning-off taps when not using the water (*i.e.* when brushing teeth), wait for full loads in washing machines, and avoid running water until the correct temperature water comes through.

HOUSEHOLD APPLIANCES

Bathroom

The bathroom uses about 30% of the internal water use (about 174 L/day) and simple behaviour such as taking shorter shower can have a significant effect upon water use without any changes to fittings. Inefficient shower heads can use 15 to 20 L/min whereas the new generation high efficiency shower heads can use 6 or 7 L/min (GWA, 2003) so upgrading the shower head will achieve even greater results and savings in hot and cold water when combined with shorter showers.

The fitting of low-flow shower heads is not suitable in all instances. Gravity flow systems, such as from elevated storage tanks, may not produce a sufficiently acceptable spray, and a special low-pressure low-flow shower head will be required. These have been around for more than 20 years; the author using one operating at 8 m head and 4L/min for an acceptable shower. The shape of the rose is extremely important. Where low-flow shower heads are installed on high pressure systems, the spray has an abrasive feel and is most uncomfortable, almost non-wetting. These systems are often in motels and caravan parks and discouraged consumers from installing similar products. Lowering water pressure is a simple solution that further reduces water while improving spray performance.

Instantaneous hot-water system may require a reasonably high flow through the system and the flow through a water-efficient device may not be enough to trip the system (ACA, 2003). These requirements need to be part of the promotional information so that consumers are not sold unsuitable products. Aerator or low-flow taps are not suitable for filling a bath because of the longer filling time and the loss of heat from the water during the filling operation, but they are ideal for the hand-basin.

It is not unusual to have long runs in the hot water pipe between the shower and the hot water tank. A standard 12 mm copper pipe has a volume of 0.1 L/m. Running the water through until the required temperature is reached can be a major loss of water. Moving the tank may not be an economic option, or physically possible; new homes should be designed to minimise such losses.

Toilet

The toilet accounts for about 25% of internal water use and other than limiting the number of flushes, changing the toilet cistern may be an economic option. It is not advisable to convert an old 11 L single flush cistern without changing the pedestal because the low-flow may not provide an adequate flush volume and solids may be left in the bowl, requiring an additional flush. In most cases a 9/4.5L flush can be fitted. For on-site systems, it is important to consider the distance from the toilet to the septic tank. Small volumes of water may be insufficient to carry solids to the septic tank and blockages in the waste pipe may occur. In new homes this longer distance can be accommodated by installing the shower or laundry above the toilet so that this hydraulic load provides additional flushing through the lines. In existing homes, this may not be achievable and medium flush toilets may be the only option.

Leaks from the toilet cistern into the pan may be visible, while at very low rates are difficult to detect. A simple check is to pour some drops of food colouring in the cistern; the appearance of colour in the pan will indicate a leak. However, modern cisterns have a top water level overflow directly into the waste pipe and cannot be seen without some dismantling of the cistern. A check that the top water level is below this overflow is a simple solution, or an overnight check of the water meter can be used to confirm leaks in toilets, or any other part of the system. Simple steps such as decreasing the volume of the cistern by adding a brick or plastic bottle filled with sand may reduce flush volumes, but residents need to be alert to any increase in the need for a second flush.

Cisterns and toilet pans tend to be very long-lived and only replaced at the time of bathroom remodeling. In some areas a 6/3 L dual flush toilet is mandatory when renovating or building a new bathroom, however, for on-site systems the distance to the septic tank needs to be considered.

Kitchen

The kitchen only accounts for about 5% of total water use and reduction in water use may not be economic, other than retro-fitting an aerator to the existing tap and reducing flow to about 8 L/min. Single mixer taps are not easily retro-fitted because of existing holes in the stainless steel sink. In new homes selection of the kitchen sink should also consider built-in screens on the drain.

Hand-dishwashing each day may use 30 to 50 L of water for rinsing, soaking, washing and final rinsing. A small kitchen sink is about 13-15 litres and the larger one up to 30 L, dual bowls having combined volumes to 60 L.

An expensive alternative to hand-washing is to install an automatic dishwasher, valued between $900 and $3000. Dishwashers are not created equal (ACA, 2003) with around 100 models of varying washing performance, drying performance, water and energy efficiency and other programming alternatives. ACA rated water efficiency only 15% of total score with washing score (40%) and drying score (20%) obviously more important. While ACA ranked washing performance there was no discussion about rinsing performance. Highly alkaline detergents (pH>11) and other chemicals may leave residues on the dishes and cutlery, and their removal should be essential in ranking overall performance.

From the details of the dishwashers on the ACA website, a summary of water use against cost of the machine (prices at June 2003) is shown in Figure 3. There is no correlation between water efficiency and price, and as water efficiency is only 15% of the overall performance score, it is expected that other operations have a higher priority and a higher cost of research and design. There is probably a minimum volume of water for a wash that can achieve the objective. Rinse aids used in the machines are to lower the surface tension of the water and aid draining and drying. This is not the same as removal of chemical residues.

Dishwashing machines certainly save water, particularly when plates are scraped prior to loading into the dishwasher rather than rinsing under a running tap. Modern dishwashers can cope with this level of soiling and a waste of water. Dishwashers also consume up to 2kW per day.

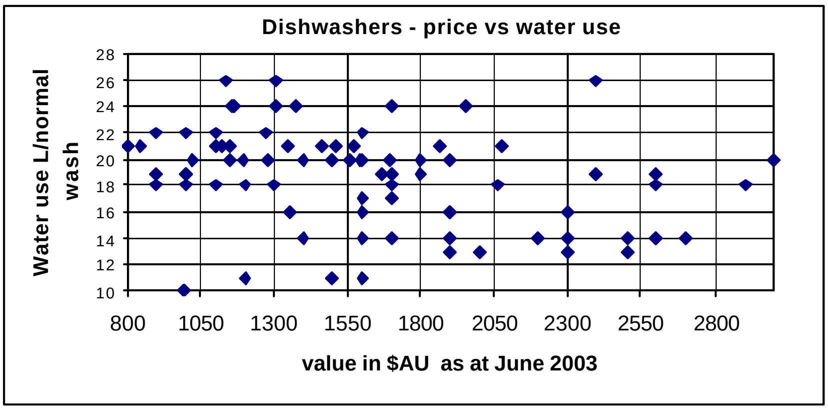

Figure 3 Dishwashing machines in 2003

Of the 90 dishwashers listed by ACA, only 12 were less than $1000, the four lowest water users ranged from $950 to $1550. The median price of all the listed dishwashers was $1560 with no correlation between price and water use (r=0.33) as other features play a larger role in manufacturing costs. ABS (2003) estimates that of the households connected to mains water, 35.3% have a dishwasher (835,000), of which 53% are less than five years old and only 20% are more than 11years (or age unknown). Until recently has been no incentive to sell dishwashers on low water use because the major metropolitan areas had not suffered the water restrictions that have become part of the normal habits of people using on-site systems. It is unclear as to whether the promotion of devices that save between two and four cents per day is justified, or simply a marketing strategy aided by the water authorities.

For on-site systems the priority of reduced water use has a higher opportunity cost because of the finite collection and storage of water and the value of water saved may not be as great as the value of land application area saved.

Laundry

About 25% of household water is used in the laundry and depending upon the type of washing machine, some reasonable savings in water consumption can be made. Patterson (1998) previously analysed information from Choice Magazines on washing machines. Figure 4 shows that for an average family with 36 kg of washing per week, there were top-loaders that use small volumes of water and front-loaders that overlapped the bottom of the top-loaders. By 2003, the situation changed and the 16 front-loaders and 25 top-loaders had a discrete separation of washing volumes, as shown in Figure 5. The average for the front-loaders was 565 L/week and 1100 L/week. At a savings of $0.98/kL, this could amount to a savings of $27.00 per year. At the current price of water, the changeover from the cheapest front-loader (5.5 kg, $1000) to the cheapest top-loader of the same size ($650) is not warranted on economic grounds as the payback period is longer than the expected life of the washing machine.

Sydney Water (2001) suggests that its demand management strategy proposes a standard of 20 L/kg of dry clothing be the upper limit for all washing machines (top-loaders and front-loaders) by 2005. This may be unreasonable unless there is an Australian standard that forces manufacturers to address rinse efficiency and lower laundry detergent use. Sydney Water (2001) states that there '*appears to be some resistance in the marketplace to shift from the traditional top-loader*'. Could it be that top-loaders offer other benefits, as well as economic advantages to the small amount of water that could be saved by replacing a working machine with a very expensive one.

Even though top-loaders are less water efficient than front-loaders, other features are obviously more important to the consumers than water efficiency. The ABS (2003) estimates on types of clothes washing machines support this observation because in NSW, 87.5% of households on mains water have top-loader. GWA (2003) state that it is not justifiable to adopt a water efficiency standard that excludes all top-loaders on the market.

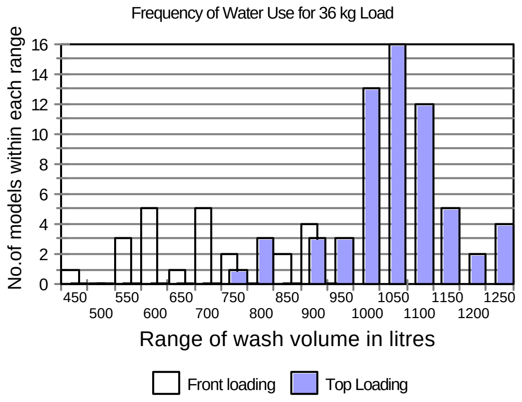

Figure 4 Washing machines in period to 1998

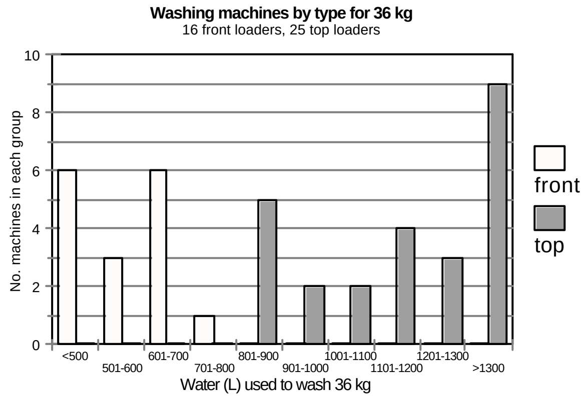

Figure 5 Washing machines in 2003

The current AS/NZS 2040.1 does not currently include a rinse test and work is continuing in the development of a suitable test that will establish that clothes have been effectively rinsed (GWA, 2003). It is important to note that for some brands of laundry detergents, the same amount (volume) is recommended for a front-loader as a top-loader (Patterson, in press) and the effectiveness of the rinse cycles may be different between the two types of machines. This one question cannot be answered without comparative data. Who provides that data is not identified in the current debate.

The emphasis on water conservation by front loaders shifts the burden on sustainability from water to electricity generation. For large capacity washing machines (6.5-8 kg), the front-loader takes at least 50 hours/year more washing time (at 36 kg/week) than a top-loader, resulting in higher electricity consumption. The savings in water may be exceeded by the increased cost of energy.

CONCLUSION

The driving forces for water efficiency come from two sectors that have different objectives. The metropolitan and urban communities have an urgency to conserve water to secure their water supplies against drought condition and increasing demand. The houses relying upon on-site systems have to reduce hydraulic load because of land application requirements. It is the need by the large metropolitan consumers that will drive the market for water efficient devices to the benefit of all.

The costs of installing water-efficient devices to achieve water conservation need to be addressed by the individual household, particular as the costs are considerably more than the cost of the devices. It is debatable whether the projected savings of 20 kL per household per year at a base water rate of $0.98/kL are efficient, as the increased energy from dish washers and front-loading washing machines may be simply shift the community's problems, and increases costs to the average household. While ever the cost of water is low, there will be no real incentive to minimise internal water use. Changing consumers' behaviour, fixing leaks and a gradual replacement of inefficient devices is likely to achieve a considerable reduction in demand. For a community that has grown to accept water on demand at a very cheap rate, this change may take years to achieve.

The current water conservation rating and labelling scheme places a greater emphasis on water efficiency that the other performance criteria that the consumers have rated a higher priority. While there is no rinse standard against which a machine's performance can be judged, the comparison between performance of top and front loaders is skewed. The higher cost of the front-loader is a significant disadvantage to a large proportion of the population, perhaps the reason for the overwhelming number of top-loading washing machines compared with front-loaders.

Water conservation is an imperative to the whole community, but other considerations such as energy inputs, performance and affordability are critical to an effective reduction in water demand.

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