GREYWATER REUSE – IMPACT OF HOUSEHOLD CHEMICALS ON USEABILITY

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ABSTRACT

Greywater reuse is the flavour of the month when water resources are rationed and there is an aesthetic and financial need to keep the home garden alive. The respective roles of regulators, inspectors, manufacturers, retailers and consumers in the consequences of greywater reuse are unclear and with more regulation become even more contorted. When wastewater chemisty is added to the areas of concern, most reuse options become extremely complex.

The consumers in Australian society believe they have power through purchasing, whereas manufacturers assume dominance through advertising. Therein lies a rational explanation why consumers buy whatever the manufacturers deems saleable, rather than act environmentally cautious. Policy makers and regulators are the end of that sequence and act as defenders of all community and environmental ideals. But is this the real world order?

This paper examines a range of domestic chemicals that have been produced for a specific outcome, often without life-cycle analysis or triple bottom line assessment. Many of these chemicals have significant impact on our environment, either alone or in combination with other chemicals or organics. Yet policy makers accept that our supermarket shelves are over-flowing with "permitted" chemicals and goals of water reuse or water conservation can be achieved by concern about microbes and pathogens, set-back distances and subsurface dispersal.

Greywater reuse is used as an example: policy-makers concentrate on faecal coliforms and salinity and consumers are ignorant of the physical and chemical changes that occur in plants and soils until the disaster has occurred. Meanwhile, new chemicals with similar or increased environmental hazards are marketed in bright and breezy packets and meaningless advertising.

Keywords: greywater, household chemicals, pathogens, salts, wastewater

1 HOUSEHOLD CHEMICALS

Whether the average Australian household has become dependent upon chemicals for every cleaning chore, as additives and preservatives to food, for remedies from indigestion to body odour and tinea, may be contested, except the multitude of chemicals arranged in row upon row of supermarket shelves convinces us otherwise. Everything from borax and honey to kill ants, to selenium sulphide to cure dandruff and cocktails of almost unpronounceable organic compounds to make our hair feel like a film star's to phosphoric acid and carbonic acid in soft drinks. What effect do these chemicals have on the soils in our greywater reuse area? Do we care? Is a measure of faecal coliform density the most valuable measure of greywater quality? How can greywater be generally described as going putrid and odorous after 24 hours?

The Australian food industry (including household chemicals) for the 2005-06 year account for $82.3 billion (ABS, 2007) of sales and the laundry detergent industry had a turnover of over $1.5 billion.

There are numerous myths surrounding the value or harm that can be derived from greywater reuse. In Tamworth in Northern NSW, a starch mill factory raises the pH of its discharged wastewater to pH 10+ to prevent bacteria decomposing the starch products and producing foul smells. If it works for commercial wastewater with BOD_5 in the range of 2000 mg/L, why does the same not happen when laundry detergent lifts the pH of washing water with a BOD_5 of < 100 mg/L to pH 10+, that is, prevent its rapid deterioration? Why do manufacturers claim that laundry detergents have a disinfection quality (which is related to high salinity and high pH), yet the regulators require laundry water to be discharged subsurface because of risks to public health. What is the real outcome?

This paper, as a follow up to previous papers by the author, examines some of the sources of chemicals in greywater that may give rise to problems in disposal areas: known problems in relation to salinity, sodicity, heavy metals and nutrient overload. Of the chemicals used in the home, there is only room in this paper to concentrate on the kitchen and laundry. The bathroom is a minefield of the cosmetic and personal grooming chemicals in every day use, soap being perhaps the lesser of all evils in this area. The data were generated from testing conducted during 2006 and 2007.

2 THREE PROBLEM AREAS

2.1 Total hardness

Unfortunately advertising, and recommended doses of household chemicals, are based upon the assumption that all domestic water is 'about' the same quality, treated to a potable level and reticulated to our homes. From this assumption, the addition of a given quantity of chemical to a particular volume of water will perform the same task whether we live in Sydney, Melbourne, Adelaide or the inland. Nothing could be further from reality, as the chemistry of potable water depends upon catchment, storage, and treatment inputs. The water property that affects the use of soaps and detergents is hardness, a quality derived from the concentration of calcium and magnesium salts (usually carbonates, bicarbonates, sulphates and chlorides) that combine with the soap to form a sticky soap curd, leading to inefficient washing. Rainwater has very little of these hardness minerals and is rated as 'very soft'. The required dose of soap or detergent is much less in rainwater than in any of the metropolitan supplies and increases with increasing hardness. Water hardness is an aesthetic, not a health or environment issue.

Table 1. Water hardness for potable water in four metropolitan supplies

Metropolitan Supply	Total Hardness (mg/L $CaCO_3$)	Source of Data
Melbourne	10-26 mg/L	(Melbourne Water 2006)
Sydney's water	50-60 mg/L	(Sydney Water 2005)
Brisbane	119-129 mg/L from Mt Crosby	(BCC, 2007)
Brisbane	69-77 mg/L from North Pine	(BCC, 2007)
Adelaide	190-323 mg/L from Anstey Hill	(SA Water, 2006)
Adelaide	262-442 mg/L from Hope Valley	(SA Water, 2006)

2.2 Phosphorus or No Phosphorus

Most of the debate about phosphorus in detergents is related to eutrophication of inland waterways where municipal sewage treatment works (STW) discharge effluent to a fresh water body. The soluble phosphorus assists the growth of algae and *Cyanobacteria;*, they bloom, produce toxins, die and the oxygen is drawn-down and aquatic life suffocates. Nitrogen is not limiting because *Cyanobacteria* have the ability to fix atmospheric nitrogen but must source inorganic phosphorus from the water column. In coastal towns where effluent (sometimes only primary treated) is dumped in the ocean, nutrient status is irrelevant, although the author does not agree with such discharge since many of the nutrients could be utilised in replenishing the soils from which the metropolitan populations are fed. Sydney Water discharged 9000 kg of phosphorus and 380 000 kg nitrogen to streams and rivers (Sydney Water, 2006) from 25% of the total wastewater generated in Sydney. The rest was discharged to the Pacific Ocean. In greywater, both these elements can be utilised as plant nutrients.

Substituting phosphorus, a builder used in detergents to immobilise (by non-precipitation) the effects of hardness, with another builder (such as synthetic zeolite-A) may solve a potential eutrophication problem, but for greywater systems on all but sandy soils has no real benefit.

Manufacturers are becoming aware of the need to reduce or eliminate phosphorus in detergents, and as most detergents are sold in large population centres, this action is to be commended. It remains to be seen what effect the replacement 'builders' will have on soil physical properties and land application.

The fact that a product contains 'no phosphorus' is only a marketing tool and, as explained later, there are benefits from products having phosphorus particularly where water hardness is a problem.

2.3 Water Temperature and Solubility

The rate of chemical interactions increases with increasing temperature, roughly doubling for each 10^{o}C rise, as does the solubility of many compounds. Greywater systems that divert water at temperatures above ambient and discharge at lower temperatures may cause components to redeposit on soil surfaces or precipitate, while discharging at high temperatures may cause soil minerals to dissolve more rapidly and be leached from their original position. Discharging wastewater from the automatic dishwasher at 60^{o}C and pH 11 is likely to have severe consequences if discharged directly to soil, before temperature reduction and buffering of pH in a treatment tank. Since washing in cold water has become more popular with detergents now effective at around 20^{o}C, the temperature of laundry discharges may not be a problem.

3 THE KITCHEN

While it is clear that kitchen wastewater is not generally a part of the greywater capture, there are households who consider the washing-up water worth saving and putting on either their compost heap (because of biodegradable greases and food scraps) or using it on their garden after some simple filtration. The chemicals used for hand dishwashing are generally pH neutral, have a high proportion of surfactant and a foaming agent. Prior to the advent of detergents for dishwashing, common laundry soap was placed in a wire basket and agitated in the water to partially dissolve some soap, creating suds at the same time. The problem with soap (formed from animal fats) is that it forms an insoluble curd with the calcium and magnesium in hard water, which sticks to crockery and reduces the effectiveness of the soap as a surfactant. Detergents, on the other hand, have molecules that form non-precipitating compounds of calcium and magnesium and allow the surfactants maximum effect.

In a recent survey of a range of dishwashing products performed for a New Zealand client, nine dishwashing liquids (hand dish-washing) and nine powders for automatic dishwashing were tested for various components that have the potential to impinge on land application. Ignoring the addition of grease and food scraps during dishwashing, there are potential hazards from salinity and pH as set out in Table 2. Total alkalinity refers to the buffering capacity of the dishwashing water. The higher the total alkalinity, the more difficult it is to lower the pH of the liquid in the environment.

Table 2 Summary of averages for hand and machine dishwashing detergents.

Detergent type	Electrical Conductivity (dS/m)	pH	Total Alkalinity (mg/L $CaCO_3$)	Sodium (g/wash)	Phosphorus (g/wash)
Hand liquids	0.087	5.9	3.3	0.167	<0.01
Automatic dishwashing	2.71	11.0	935	10.3	2.1

4 THE LAUNDRY

4.1 Test Volumes

In recent months, analyses were conducted on powder laundry concentrates which were mixed at two rates for wash only: one for front loaders; and one for top loaders. While it is well established that front loaders use less water than top loaders, the difference in wash water quality is poorly understood. Environmental gains from using less water may be quickly compromised by increased salinity, sodicity and phosphorus loads from the larger dose of detergent used in front loaders to compensate for the washing action.

A difference in the all reported results occurs when the wash cycle water is used as greywater separately to the whole cycle water. The wash cycle is that part of the cycle in which the detergent is agitated with the clothes and this wash water is then dumped. The whole wash cycle includes the wash cycle, with the spin, deep rinse and spin rinse water. For front loading washing machines the wash water may be as little as 25 L while the whole wash is 55 L; for a top loader the wash may be 60 L and the whole cycle 150 L. These quantities vary from machine to machine and are not easily obtained from the advertising literature, the manual that accompanies the machine or the Water Efficiency Labelling Standards (WELS) Scheme website. Therefore, the results reported here are for the range of water quality based upon front loaders 15 L wash, 75 L total, and the top loader at 27 L wash and 150 L total cycle. With different branded washing machines using variable volumes at each step, plus programmable settings for water volumes, there is no simple result. Add to these variations, water quality (hardness, salinity and pH) and variable doses and the greywater quality can only be expected to fall within a range for each detergent, rather than definitive results.

4.2 Consumption Rates

The volume of soaps and laundry detergents used in Australia in 1998-99 was reported by ABS (2006) as having a combined local and imported value of $1,455 million. At an average cost of production of $3.00/kg (allowing for a retail price of $5.86/kg) some 500,000 tonnes of soaps and detergents enter the wastewater system each year, amounting to more than 25 kg/person per year! This consumption fits with previous research by the author (Patterson, 1994). Any small reduction in this load has the potential to reduce the environmental impact on the receiving water or soils as well as a reduction in energy to produce and transport the detergent. The move to concentrates and tablets is one strategy for reducing salinity, while liquid detergents have less impact on salinity, sodicity and total alkalinity. Many front loaders are not capable of using liquid detergents.

The dose for front loaders ranged from 10–130 grams/wash (average 64 g/wash), while for top loaders the range was 24-123 g/wash (average 80 g/wash). These ranges suggest that selection of a suitable product is difficult but there are products for each machine type that have small doses. The powders specifically formulated for front loaders (**Matic) averaged 104 g/wash, and as many were 'so called' concentrates, these amounts are high. The cost per wash is based upon the dose per wash. Unfortunately, other than a couple of products with the number of washes marked on the packet (for example BioZet™), the calculation of number of doses per kilogram pack cannot be done. Therefore, there cannot be an 'in aisle' comparison of one product at $6.00 per kilogram with another at $4.75/kg, because the measured doses recommended on the packet are in scoops or other volumetric measures when the products are sold by the kilogram.

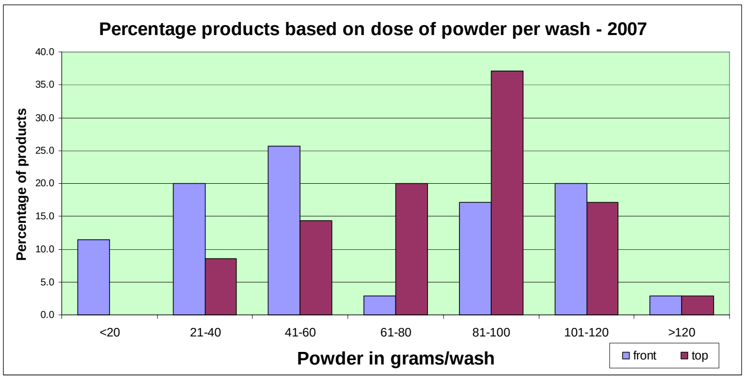

Figure 1. Percentage of products within each dose range

Figure 1 shows the percentage of products within the dose ranges. It is possible to choose products with a low dose, and by inference, a greater number of washes per kilogram.

A more difficult decision comes with taking an appropriate dose when many products only recommend a dose based upon a 'normal' or a 'heavy' wash. What interpretation these terms have is anyone's guess.

As for the statement about using more detergent in hard water, there is no qualification as to what level of hardness the recommended dose was set, and what constitutes hard water. These statements are but some of the misinformation directed at consumers. One also needs to consider the difference between a 5 kg machine and a 10 kg machine, with no recommendation based upon machine capacity. Since dose and water volume with load capacity would seem to be connected, such association is difficult to fathom from much of the advertising material on the packet.

4.3 Salinity Issue

While greywater may be a resource for maintaining a garden or lawn during periods when reticulated water is restricted, the detergents used in the laundry must be recognised (?) as a salinity risk. The risk is associated mostly with powder detergents and the higher the dose of detergent recommended, the higher the potential risk. Since salinity is the measure of all the salts in a detergent, a simple measure is to multiply electrical conductivity (EC) (in units of deciSiemens/metre) by 680 to derive salinity (milligrams/L). In laundry liquids there are more organic compounds that do not ionize to affect measured EC, yet may impinge upon soil properties and soil microbiological activity. That their hazard is not measured is open to future research projects.

A difference in the salinity level occurs when the wash water is used as greywater separately to the whole cycle water as discussed above. It can be expected that the same dose of detergent in smaller sized front loading washing machines will give a more concentrated wastewater (higher EC) than a similar dose in a large top loader, but the salt load reflects only the actual dose of detergent irrespective of the volume of water, or whether we use wash only water or whole wash cycle volumes.

Where the volume of water becomes important is in the distribution of the greywater over a garden or land area. The larger the volume of water, the easier it is to spread the saline load and therefore reduce the impact. Small concentrated volumes are difficult to spread over large areas. For this reason, Table 3 reports EC so that the differences become clearer.

TABLE 3. Electrical conductivity for powder and liquid laundry detergents

Cycle	Statistic	Liquid		Powder	
		Front loader	Top loader	Front loader	Top loader
Wash only	Range (dS/m)	no test	no test	0.78 – 7.30	0.49 – 2.70
	Average (dS/m)	no test	no test	4.00	1.72
Total cycle	Range (dS/m)	0.04 – 0.44	0.01 – 0.73	0.14 – 2.73	0.10 – 2.83
	Average (dS/m)	0.10	0.10	1.18	0.91

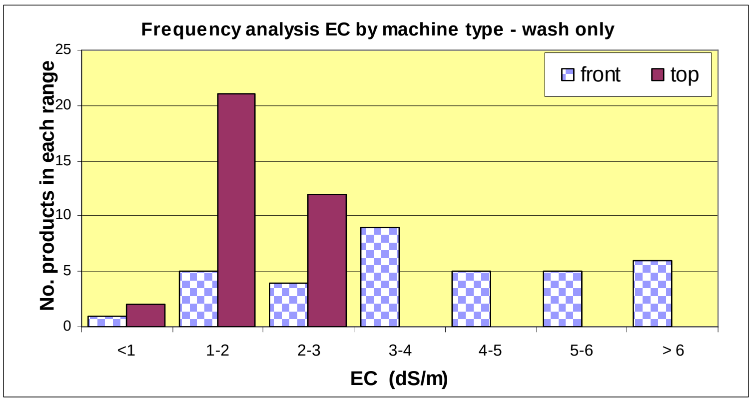

Figure 2. Comparison of EC for wash only

In terms of powder products in a 'wash only' volume, Figure 2 shows that a larger number of products produce higher EC values in front loaders than top loaders. The effect of high salinity could be overcome by wise choice of products; however, current labelling prevents one from knowing the sodium load in a powder detergent. While standard powders can be expected to have a higher proportion of 'builders', concentrates have minor amounts. Thus, front loaders may be more environmentally unsound than their competitor top loaders.

4.4 pH

Biological systems prefer a range of pH 5.5 to 8.5, although many organisms live in extreme conditions. Highly acidic or highly alkaline greywater can change the solubility of soil minerals and affect any nutrient balance that may have existed before the greywater dispersal. High pH wastewater may also dissolve metals from the fittings and fixtures. It is clear from Table 4 that liquid detergents have a pH closer to neutral than the powders that are highly alkaline. Add to the high pH the total alkalinity (buffer capacity) and the powders in wash become even more environmentally hazardous.

TABLE 4. Ranges and averages for pH and total alkalinity at various mixing ratios

Cycle	Statistic	Liquid		Powder	
		Front loader	Top loader	Front loader	Top loader
Wash only	pH range / average	no test	no test	10.15 (10.81)	11.10 (10.52)
	Total alkalinity /average (mg/L)			350 – 3500 (1770)	170 – 1100 (575)
Total cycle	pH range / average	5.18 – 10.18 (7.95)	4.98 – 10.17 (7.88)	9.40 – 11.09 (10.55)	9.39 – 10.95 (10.48)
	Total alkalinity /average (mg/L)	20 – 150 (38)	20 – 100 (36)	50 -1130 (432)	40 – 940 (220)

Note: deionised water used for test had pH 5.00, total alkalinity <1 mg/L $CaCO_3$

Perhaps the reason our clothes deteriorate is not through wearing them, but by dissolving them in the extremes of laundry powders.

4.5 Sodium Adsorption Ratio (SAR

The analyses for both sets of tests were performed with deionised water (EC=0.005 dS/m, pH= 5.00), which is equivalent to very clean and fresh rainwater. Town water supplies are highly variable, with coastal towns in NSW having water of a higher quality than inland towns with respect to total dissolved solids (TDS) or salinity. Sodium, calcium and magnesium are at very low concentrations in coastal supplies but may be high in inland town water supplies due to the geology of particular catchments (Patterson, 1994). The values measured for the two sets of tests have been recalculated for Sydney's water quality, based upon values reported by Sydney Water for Nepean Water Filtration Plant for sodium, calcium and magnesium as 11 mg/L, 18 mg/L and 2.7 mg/L respectively. Patterson (1994) showed that soil permeability started to diminish at SAR 3 and decreased as SAR increased.

TABLE 5. Sodium adsorption ratio for various mixing rates using Sydney Water

Cycle	Statistic	Liquid		Powder	
		Front loader	Top loader	Front loader	Top loader
Wash only	Range	no test	no test	9.3 - 220	6.2 – 43.8
	Average	no test	no test	83.0	24.4
Total cycle	Range	0.2 – 7.7	0.03 – 4.6	1.8 – 41.0	1.2 – 37.7
	Average	1.4	1.2	16.5	11.7

The lower the SAR, the lesser potential for the greywater to influence soil instability or upset the sodium balance in the plants. Under Australian conditions, an SAR of 5 is taken as the threshold. However, Quirk and Schofield (1955) showed that permeability could be maintained when the EC was elevated above the threshold electrolyte concentration (TEC). This TEC varies with soil texture and is determined empirically. This theory suggests that as SAR increases, there needs to be an increase in EC to overcome the propensity to disperse. This effect can be seen in practical application of gypsum to dispersible clay soils. The increase in soil solution's EC due to the presence of gypsum (sodium sulphate) reduces the effects of sodium on clay dispersion.

4.6 Phosphorus in Detergents

As stated earlier, the choice of detergents containing phosphorus within limits (symbol P) and those without added phosphorus (symbol NP) is more a consideration of the possible consequences of the greywater influencing eutrophication. The 'P' label is an industry standard that indicates a product has less than 7.8 g P /wash, a value that equates in the wash to 50 mg P/L. It is interesting to note that while none of the products tested exceeded this value, the spread of 'P' labelled detergents covered the whole range up to 7.8 g/wash. Products that were labelled 'NP' were essentially phosphate free. Some products carry no phosphorus labelling where some did and others did not contain phosphorus.

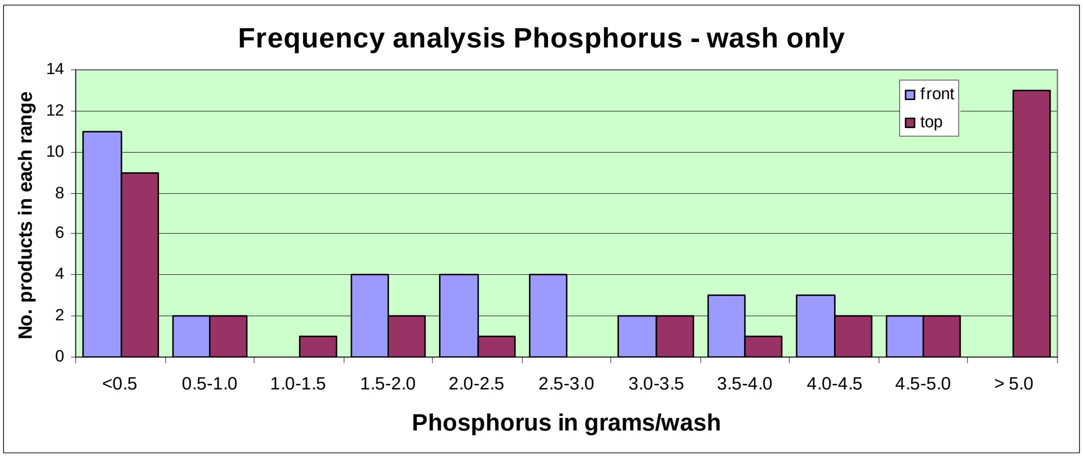

Figure 3. Number of products within range of phosphorus loads for wash only

The consumer does have a choice of phosphorus loading and the labelling on the packet provides sufficient information to make an informed choice. However, unless the alternative builder is as successful as phosphate builders in isolating the hardness of the water, the increase in powder use required to overcome hardness may be uneconomic. For those consumers using rainwater, the only hardness is from the dirt in the clothes and phosphate-free detergents are more than satisfactory.

4.7 Wash and Rinse Efficiency

The author worked collaboratively with the Australian Consumers' Association (ACA) in the 2007 round of powder laundry detergent tests; ACA published the results of their wash and rinse performance tests in the April edition of 'Choice Magazine'. Choice gathered performance results for wash and rinse efficiency, water and energy use to derive an overall score. Patterson (2007) showed that when the results for only wash and rinse efficiency were averaged, the front loaders performed second to the top loaders in all capacity categories. Other than for water saving, there is little to commend the front loaders. If rinse efficiency, the Standard for which only became mandatory in July 2006, is important, then top loaders win the day. Unfortunately, the power of advertising and rebates tipped the balance against the top loaders at the expense of the environment for greywater reuse.

The powders specifically formulated for use in front loaders had the highest phosphorus load of the 35 powders suitable for front loaders (some powders are suitable in both front and top loaders) with 3.5 to 5 g P/wash. Similarly these special powders were at the top of the graph for sodium with 30-60 g Na/wash, and at the top of the EC graph for the highest EC of all the front loaders.

4.8 Other Important Matters

Biodegradability is a concept that appears to have been gathered by environmental activists at the expense of science. A product can only be degradable, by definition, when it is an organic compound. The organic components in laundry powders are usually the surfactants, the perfume and the cardboard box. The remainder is inorganic that can never be 'biodegradable'. Therefore, for manufacturers to boldly display the term 'biodegradable' without the qualification as to only the organic components, then they are relying upon ignorance among the community. More robust labelling requirements would go a long way to addressing misunderstandings about laundry detergents and the environment.

Greenhouse gas emissions come from carbon dioxide (sodium carbonate in detergents) and other gases generated from the decomposition of detergents, plus the energy used to produce the washing machine, deliver and heat the water, manufacture and transport the detergents, and degrade the wastewater generated. The carbonates in detergents decompose to produce carbon dioxide and the sulphates are reduced to form hydrogen sulphide in anaerobic conditions. That laundry detergents, including common soap, should be considered additive to the greenhouse gas emissions is probably years from being proclaimed, let alone measured.

5 CONCLUSION

It is reasonable to expect consumers who wish to reuse their greywater on the garden or lawn can do so with some certainty that the chemicals they have used in the bathroom and laundry will do little harm to the soil, plants and soil biology. Any listing of components in the detergent is hardly designed to be informative of its impact on the environment. Unfortunately, household chemicals are not marketed for greywater systems but for the masses in metropolitan areas. Influences on detergent dose such as hardness, wash volume, machine capacity, hot or cold water are poorly understood and product labelling does nothing to advance understanding.

There is an increasing awareness of the need for reduction in phosphorus in detergents, but the replacement compounds have not been shown to have a reduced environmental impact. Few manufacturers are moved to reducing the sodium load because sodium salts are cheap and always soluble. However, with increasing awareness of the need to reduce salinity, sodicity and nutrient loads, dispersal of greywater over larger areas may become the norm, rather than tipping the greywater on the same spot in the garden, day after day.

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