ASSESSING SUSTAINABLE GREYWATER REUSE AND APPLICATION RATES

Joe Whitehead[1] and Robert A Patterson[2]

1. University of Newcastle 2. Lanfax Laboratories Armidale

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J H Whitehead[1] and R.A Patterson[2]
1. University of Newcastle, Callaghan, NSW 2308 2. Lanfax Laboratories, Armidale
Corresponding author's email: joe.whitehead@newcastle.edu.au

ABSTRACT

Land application of both treated and untreated greywater is being strongly promoted by governments and increasingly adopted by homeowners as a partial remedy to chronic water shortages and imposed water restrictions. In most instances untreated greywater is diverted for land application using simple greywater diversion devices. In far fewer cases, but increasing in number all the time, more expensive greywater treatment systems are being used, which provide higher quality effluent fit for a wider range of uses. Greywater reuse for irrigation provides an alternative source of water to help sustain gardens during times of water shortages, however, often only limited consideration is given to potential impacts caused by the hydraulic load, nutrients and other constituents of the greywater which can be present at similar or even higher concentrations than in treated domestic wastewater. Information provided by governments on safe application rates and management of reuse systems is simplistic. Regulation of greywater reuse relies heavily on homeowners being actively involved in the management of their system and doing the right thing, in stark contrast with the regulatory approach to domestic wastewater management where governments adopt a much more conservative approach and assume that homeowners are neglectful and will not properly manage their system.

This paper reviews the guidance given in NSW by the NSW Guideline for Greywater Reuse in Sewered, Single Household Residential Premises (DEUS, 2007), and compares this with equivalent standards and guidelines for domestic wastewater management, highlighting some significant disparities. We investigate the development of sustainable greywater application rates (to land) using water and nutrient balances and present case studies of typical domestic situations as examples.

Keywords: greywater, guidelines, nutrient application rates, recycling, reuse.

1 INTRODUCTION

The current drought conditions across Eastern Australia have resulted in water storages being at record lows. Combined dam water levels for SE Queensland on 7 September 2007 were at 20.56% (Queensland Water Commission 2007). On the same date Melbourne's water reservoirs were 38.7% full (Southeast Water 2007). In NSW, Warragamba Dam (Figure 1) has had less than 55% of full operating storage for a period in excess of three years since early 2004 (SCA 2007).

In Victoria Stage 3a water restrictions have been in place since April 2007. In Sydney, NSW, Level 3 restrictions apply to all Sydney Water customers including residents, businesses, local councils and government agencies. In Queensland, Level 5 restrictions apply and the Government seeks to restrict daily average water consumption to 140 litres per person. Interestingly 140 litres per person per day is the typical wastewater flow allowance for households with standard fixtures and on-site roof water tank supply quoted by the Standard AS/NZS 1547 (Standards Australia 2000). Water restrictions are now commonplace and have a significant impact on major metropolitan areas that depend upon storages away from the direct influence of coastal storms.

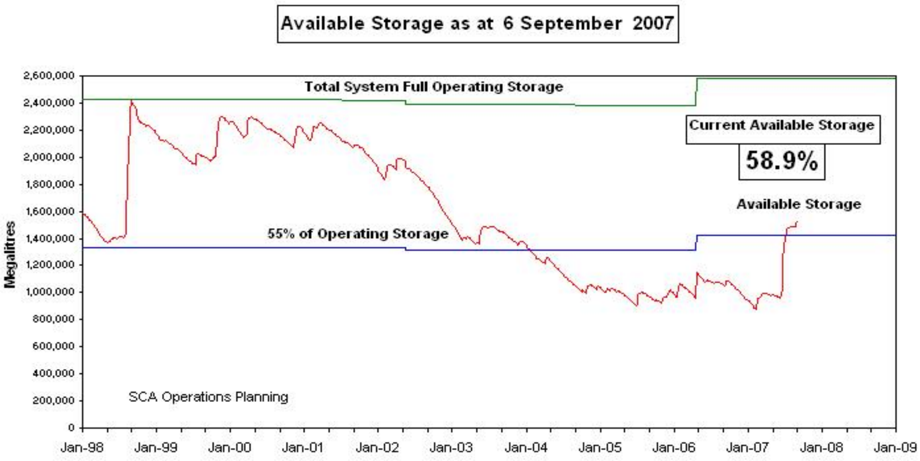

Figure 1. Storage at Warragamba Dam (SCA 2007)

Part of the political solution has been to encourage the reuse of greywater from the laundry and bathroom while making it clear to exclude kitchen and toilet wastes. Other encouragements to the general populace are rebates for purchase of front-loading washing machines, installation and connection of rainwater tanks for laundry, toilet flushing and garden use, low-flow shower heads and dual-flush toilets. There are potentially significant savings in daily water consumption to be gained if these water conservation issues are widespread, but there is a catch. The rebates are subsidies that may be as little as 10% of the purchase price of the replacement product. In the case of the $150 rebate for front-loading washing machines, the average cost of an approved type is $1,500 (Patterson, 2007a). The other option to water conservation is water reuse. While the two are not mutually exclusive, finances play a major role in which route an individual household follows.

Over the past few years, most Australian States have developed guidelines (which in some cases are still in draft form) for the treatment and reuse of greywater, although there is still conjecture about its treatment and storage given the known public health and environmental issues. Guidelines vary between States and within States, particularly where the local regulatory authority (the council) manages the practical aspects associated with the interpretation and application of the guidelines (Geary *et al*. 2005). Many of these guidelines do not provide clear cut and authoritative advice, many lack or only have limited reference to published literature and the informed reader might readily get the impression that they have been written to satisfy the needs of political masters rather than with the conviction of sound science, engineering and management principles.

2 NSW GUIDELINES FOR GREYWATER REUSE

In March 2007, following the earlier release of a draft for public comment, the NSW Government published the NSW Guidelines for Greywater Reuse in Sewered, Single Household Residential Premises (DEUS 2007) (the *Guidelines*). These guidelines introduce greywater and greywater characteristics, describe greywater diversion devices (GDD), greywater treatment systems (GTS) and manual bucketing of greywater and has a number of supporting appendices and fact sheets (only two of the five described are currently available).

The *Guidelines* describe GDD and indicate that greywater from a diversion device is untreated and must only be reused for subsurface irrigation. GDD are exempt from plumbing approval if they are WaterMark-licensed. NSW Health has a register of WaterMark-licensed gravity and pumped GDD (NSW Health 2007). It is evident, however, that many GDD on sale at hardware stores are not WaterMark-licensed, and, indeed that relatively few of the GDD sold *are* WaterMark-licensed. The *Guidelines* also require that a licensed plumber must install the GDD, but licensed plumbers report installing few such devices. It is likely that homeowners install a large proportion of the GDD sold (of which one imagines there are many, as they are promoted strongly by hardware stores) without reference to either licensed plumbers or local councils. Many of the GDD available on the market are not designed for or would be ill-suited to subsurface irrigation, so it is reasonable to presume that many GDD installed by homeowners discharge untreated greywater directly to the surface. A small number of GDD available on the market do appear to have been better designed for the purpose, and offer surge tanks, some screening of the greywater and subsurface irrigation by either pump or siphon, and clearly these do a far better job of applying greywater to land than many of the readily available but unapproved devices.

The *Guidelines* describe Greywater Treatment Systems (GTS) that collect, store, treat and may disinfect greywater to standards specified in the NSW Health Domestic Greywater Treatment Systems Accreditation Guidelines (February 2005) (NSW Health 2005). A list of accredited GTS also appears on the NSW Health website. Councils must not approve GTS unless they are NSW Health accredited. The *Guidelines* indicate that a licensed plumber must install the GTS and that the irrigation system associated with the GTS does not require accreditation by NSW Health. Although the *Guidelines* indicate that a licensed plumber should install the irrigation system associated with a GTS, this is at variance with the corresponding guidance on installation of irrigation systems associated with on-site wastewater treatment systems. NSW Health-accredited GTS are generally much more expensive than GDD, commonly within the $5,000 - $15,000 price range. Their price clearly not only limits the number of systems installed, but also ensures that for the most part they are installed professionally and are much less at risk of being installed inappropriately by homeowners who may not relate to, respond to or even be aware of the relevant regulations and guidelines. Whilst the outcomes in terms of treatment quality will vary, many of these systems when properly installed, serviced and maintained, will produce high quality treated greywater which is likely to have minimal adverse impact on the receiving environment.

A recent report by Queensland's Premier (Queensland Government, 2007) revealed that of the $103 million paid in rebates between July 2006 and August 2007, rebates for only 1001 greywater systems worth $57,000 had been paid, an average rebate of $57, a small proportion of the cost of installing any greywater treatment system. Compared to the rebates for 89,066 rainwater tanks ($87.3 million) and 57,409 washing machines ($11.5 million), it could be interpreted that greywater systems are a very low priority, representing only 0.06% of the total rebates by value and 0.6% of the number of applications. The $102 million is only the value of the rebates, not the total cost of purchase and installation.

3 POTENTIAL FOR ENVIRONMENTAL AND PUBLIC HEALTH IMPACTS

GDD, particularly those without WaterMark-licenses, discharge greywater to the environment in a largely uncontrolled and unregulated manner. It is quite possible that such devices exist in large numbers and possibly quite high densities in urban areas that have been or continue to be affected by drought driven water shortages. Regulators do not necessarily know these systems as there is no requirement that they be formally registered and they may only come to the attention of regulators if they give rise to environmental or pubic health problems. They discharge largely untreated greywater, commonly with no control which ensures that they diverted to sewer in periods of wet weather and may well discharge on to saturated ground which lacks the hydraulic capacity to manage the additional greywater. There is no requirement that any site and soil assessment be undertaken to determine the suitability and hydraulic capacity of the site for the application of greywater at the rates at which it might be generated. No consideration is given to the level of treatment, which quite commonly will be low at best and may well be ineffective at reducing any of the contaminants in the greywater stream at all. The vegetation and soil are subject to potentially significant nutrient and salt loads and surface waters to nutrients, salt, fats, oils and greases and possible pathogen loads depending on the greywater source. The potential for these impacts to be adverse is commonly given only limited and in some case scant coverage in the various State guidelines and rarely is the potential for cumulative impacts even raised.

4 DOMESTIC GREYWATER GENERATION SCENARIOS

Two domestic greywater generation scenarios are considered using the *NSW Guidelines* as the basis for quantification of greywater generated. The potential loading rates to soils are determined as if the greywater load is irrigated on to a 20 m^2 area of garden, which might typically be the area effectively irrigated by a cheap, off the shelf, unapproved GDD.

4.1 Scenario 1

What is the approximate average daily greywater generation rate for a family of two retired adults who each take one half-full bath daily and do three loads of washing in their 7 kg top-loading washing machine per week?

No of persons	= 2	
2 baths x 125 litres x 7 days	= 1750 litres/week	
0 showers x 0 litres x 0 days	= 0 litres/week	
3 washes x 128.5 litres	= 385.5 litres/week	
Total	= 1750 + 385.5	= 2135.5 litres/week
2135.5 litres/week/7	= 305 litres/day	
305 litres/day/20m^2	= 15 litres/m^2/day	= <u>15 mm/day</u>

4.2 Scenario 2

What is the approximate average daily greywater generation rate for a family of two adults and four children? The adults each take a five-minute morning standard shower daily and share a half-full bath on Saturday night. The children share two half-full baths each evening. The 9.5kg top-loading washing machine runs once each day in the morning and in addition once each evening on weekends?

No of persons	= 6	
2 baths x 125 litres x 7 days	= 1400 litres/week	
1 baths x 125 litres x 1 days	= 125 litres/week	
2 showers x 100 litres x 7 days	= 1750 litres/week	
9 washes x 184 litres	= 1656 litres/week	
Total	= 1400 + 125 + 1750 + 1656	= 4931 litres/week
4931 litres/week/7	= 704 litres/day	
704 litres/day/20m^2	= 35 litres/m^2/day	= <u>35 mm/day</u>

These two scenarios demonstrate that if all available greywater is diverted to irrigation of 20 m^2 of garden, untreated greywater loading rates on soils are likely to significantly exceed those permitted for secondary treated wastewater, which range from 2-5 mm/day for a range of soils from heavy clays to sands or gravels.

5 IRRIGATION AREAS FOR RECYCLED WATER

Sydney Water reticulates reclaimed water from the Rouse Hill Sewage Treatment Plant (STP) into more than 16 500 homes (eventually 35 000) around Rouse Hill for flushing toilets, watering gardens washing cars and other outdoor uses (Sydney Water 2007). The quality of the water available has total dissolved solids of 540 mg/L, total nitrogen (TN) of 7 mg/L and total phosphorus (TP) of 0.1-0.3 mg/L (Sydney Water, 2004). These values can be used to calculate the land area required to appropriately assimilate the nutrients. Many parts of Western Sydney already suffer from significant soil salinity issues (Holmick *et al.*, 2007) and increased salinity through the external use of Rouse Hill recycled water may exacerbate salinity issues. Sydney Water has the ability to dilute the recycled water with potable water to maintain the desirable TDS.

An assumption is made for a combined lawn and garden area of 200 m^2 and an irrigation application of 20 mm of recycled water each week (consistent with AS/NZS 1547 for a light clay, although the Standard is designed for disposal and not propagation). Thus, for an annual nutrient budget, 208 kL of recycled effluent would have 112 kg salt, 1.5 kg TN and 62 g TP or 5.6 tonnes salt/ha, 75kg N/ha and 3 kg P/ha. The TN and TP are well within expected requirements of lawns and gardens (250 and 30 kg/ha respectively) but the salt load is excessive and likely to lead to salinity problems other than just the loss of plant health.

5.1 Reuse of Household Greywater

The calculations performed in the previous section for municipal recycled water are equally pertinent to reuse of greywater from single households, and perhaps more critical in households where water conservation is practised, and chemical use continues unabated. Patterson (2007) states that the use of front loading washing machines and the specially formulated powder detergents (usually labelled **Matic) used an average of 104 g/wash compared with the average for that machine type of 64 g/wash. Therefore, these special detergents add more salt to the wastewater than traditional powders and significantly more than liquid detergents (many front loaders cannot use liquid detergents).

Other water conservation measures such as low-flow showers may increase salinity of the wastewater generated. Do you use less soap under a slow shower, or the same amount of soap, washed off with less water? The answer determines how the greywater may be discharged over the lawn or garden.

5.2 Conservation or Greywater Treatment

Water conservation is but one issue for the economics of supply of water in the home. Whether one treats greywater for reuse as irrigation during periods of water restrictions or simply re-landscapes with xerophytes and low transpiring plants is a matter of choice. Adding stormwater capture and storage may be a more economic proposition and provides water savings at all times. The issue in treating greywater is whether the quality of the water after treatment is suitable for irrigation around the home. Increases in salinity in close proximity to buildings may, in time, cause problems. The recent report by Queensland's Premier that rebates for 89,066 rain tanks compared with 1001 greywater systems certainly indicates that preference for Queenslanders for additional water capture rather than greywater reuse. Perhaps the difficulty with regulations may deter people.

5.3 Reverse Calculation of Greywater Irrigation Area

While the method illustrated above can be used to calculate the salinity, TN or TP load for a back yard of a particular area, the reverse can also be done to determine the area required for a laundry powder of a particular concentration of salt or phosphorus. Very few products have sufficient TN to bother doing the calculation. As an example, the quality of laundry product A when mixed for a whole-cycle in a four-star front loader (say 75 L) gives pH 10.9, 103 g salt/load, 32 g Na/load, and 4 g P/load (actual readings, product name withheld). While pH may indicate a likely impact, particularly from alkaline wastewater, it is the salt load, the sodium (Na) load and the phosphorus (P) load on which the estimates will be done.

5.4 The Scenario

The results of the calculation are set out in Table 1 so that other scenarios may be tried. The lawn will not suffer too badly from the equivalent of 1 tonne salt/ha, 400 kg Na/ha, or 30 kg P/ha. There may be some soil adsorption of phosphorus so the value is changed to 60 kg/ha (soil dependent). The other part of the scenario is that one wash per day is typical of the average household; 60 L per day is 22 kL/year. Table 2 provides the answers to those calculations.

Table 1. Calculation of greywater chemical loads for an average household garden

	Salt Load	Sodium load	Phosphorus Load
Annual sustainable load (kg/ha)	1000	400	60
Load per wash (kg/wash)	0.103	0.032	0.004
Load per year (kg/year)	37.6	11.6	1.4
Area required (m^2)	375	290	235

The area required for that particular front loading powder depends upon whether you consider salt, sodium or phosphorus the most critical for maintaining plant health. There is no evidence to show that phosphorus is detrimental to Australian natives, except the Proteaceae family. The need to be sustainable indicates that you need to spread the water from your front loader over at least 375 m^2 of yard, that is if you have that area available and have the equipment to ensure even irrigation of the whole area. If not, then you need to change to detergents that suit a smaller footprint for irrigation.

5.5 Greywater Chemistry

In all fairness to the general public, individuals cannot be expected to choose products that will have the lowest impact when greywater is reused for landscape irrigation around the home. What plants will survive? Are the plants salt tolerant? Is there a difference between salt tolerant and sodium tolerant? There are no labelling codes for laundry detergents, wool washes, fabric softeners, or the myriad of bathroom products from hair shampoos to body washes. Popular television gardening programs promoting greywater recycling without addressing the likely impacts from wastewater chemistry, or the need to ameliorate some soils before, during and after greywater application are counter-productive to beneficial reuse. There are real needs for accurate information on product labelling and penalties for 'distorted' advertising and a government backed 'minimum' labelling code in the same style as food labelling. Such labels should indicate potential salinity harm, sodium and phosphorus levels at a minimum. Each product needs to carry a label indicating product dose in the same units of measure as the product is sold, that is, if a product is sold by mass, the dose must also be in mass units. It is common that laundry detergents are today sold by mass and the dose recommended by volume, a confusing and misleading statement.

6 THE MISSING VARIABLES

6.1 Water Flow and Irrigation Rates

The variability of water flow rates from the bathroom and laundry make the irrigation of effluent that is not collected in a small storage tank, difficult. If the effluent cannot be stored, then how and when do you irrigate with water that has come from the shower at 11pm and only enters a GDD and there is insufficient water to even charge up the delivery pipe to the subsurface irrigation. Therein lies a real quandary. GDD do not treat greywater (NSW Health 2000), they may provide coarse screening, but above all greywater must not be stored. Is this latter statement a myth?

Next comes the five loads of washing that are done on Saturday because everyone is working during the week; sports team outfits might need washing and so too bedding etc. Without an adequately proportioned collection well (more than a surge tank), any subsurface irrigation area is likely to be surcharged with laundry water, irrespective of what condition the soil is in. Or, in the case of a small surge tank, excess water will be wasted to sewer. The solution appears to be only for the installation of a GTS. A GTS "collects, stores, treats and may disinfect all or any of the sources of greywater to the standards specified in the NSW Health Accreditation Guideline for GTS" (NSW Health, 2000).

The question we pose is "How is the homeowner going to know and behave in the manner expected?" The answer is distorted by the significant variability, by the hour, of the volume of water and its chemistry that may be available for greywater reuse.

6.2 Soil Variability

NSW Health (2000) quotes the Environment and Health Protection Guidelines (DLG, 1998) with regards to how domestic wastewater may harm the environment, particularly the soil, many of the likely changes such as salinity, soil permeability, sodicity, cation exchange capacity (CEC), soil dispersion and phosphorus sorption. There are few in the general community who understand the terminology and most impacts need to be assessed through laboratory analysis. Anything less is not even a best guess, and so environmental consequences enter the realm of the unknown.

Based upon the Australian Soil Series Classification (Stace *et al.* 1972) there are 43 Great Soil Groups in Australia. Except for a couple of soils, almost no research has gone into the impact of greywater on the various soils on which our population resides and yet they are encouraged to irrigate greywater to save drinking water. Certainly Government funds to cover such research are mostly non-existent.

So, again a question: what is the impact of laundry water on soils within your local government area? The answer has to be one of silence. Yet there is a constant message that reuse of greywater is a desirable outcome in a time of drought. And what happens when water restrictions are relaxed?

6.3 Influence of Greywater on Soils

There are broadly three distinct soil textures – sand, loam and clay, with infinite variability among them. The behaviour of each of these to permeability ranges from rapid in sands to very slow in clays. Sands are less than ideal for greywater application because they fail to impede the downward movement of water sufficiently to remove the nutrients, while the loam and clay reduce the rate so that plants may access the passing nutrients. With lower nutrient assimilating capacity sands may seem to work well but that is an appearance only. Clays, however, can tolerate higher soil salinity than clays without limited plant growth to the same extent.

What of the fertilizer value of greywater? Table 1 indicated that the greywater from the laundry for a year amounted to 1.4 kg, yet 38 kg of laundry detergent was consumed at an average cost of $5.00/kg equating to $190.00. At current garden nursery rates, phosphorus (as superphosphate) is valued at about $25.00/kg. At least in reuse, the phosphorus does not end up as a waste at the municipal sewage treatment works. As for the salt, it is detrimental to plants and soil stability.

Amelioration is the 'rage' in gardening circles. Lime, dolomite, organic matter, chook manure and horse manure are all high on the gardener's agenda. Some of these products are essential to the greywater irrigation area because they can increase the calcium levels to overcome sodium's influence, or increase the organic content and its high cation exchange capacity. Unfortunately, very little advice is offered by the proponents of greywater reuse as to the need to ameliorate the irrigation area. That gypsum is recommended may be most inappropriate. Perhaps the reason for this vacuum is that where greywater has to be discharged below ground level, surface application of ameliorants may take years to leach into the soil below the subsurface drippers, so why bother. With hindsight, perhaps the subsurface discharge of greywater serves but a minor purpose yet a 'ticking' disaster.

What is "garden-friendly and biodegradable"? DEUS (2007) uses these terms as if the consumer may have some insight into their meaning. Since many of the chemicals we use in the home are garden unfriendly and biodegradable only refers to the organic components of a product (at least the cardboard box), there is real misinformation at work.

7 CURRENT GREYWATER REUSE GUIDELINES

Confusing they may be, but many of the guidelines are enshrined in legislation, most often in regulations because these require no parliamentary scrutiny, and them we must obey. So just how confusing are they?

As an example, "Where the treated and disinfected greywater meets a 30 cfu thermotolerant coliform / 100mL disinfection criteria it may be utilised by surface irrigation in a properly designed land application area. Where the treated and disinfected greywater meets a 10 cfu thermotolerant coliform / 100mL disinfection criteria it may also be used for toilet and urinal flushing and laundry use" (NSW Health 2000). The DEUS (2007) guidelines only state that the greywater must be treated in a GTS for use for toilet flushing or the washing machine and no mention is made of any particular standard. It is difficult to comprehend that greywater which has an unknown chemistry can be used for washing clothes (assume washing also means rinsing) yet the only determinant is the quality of the water that was tested in a certification round. It is clear that the general community is getting mixed messages. Add the NSWRWCC (1993) guidelines and the requirement for toilet flushing and washing machine use is a three-monthly rigorous testing regime with no detectable virus (<2 in 50 L) or parasite (<1 in 50 L) and faecal coliforms (<1 cfu/100 mL). It appears that standards for the treatment of water to be used for toilet flushing are most confusing.

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