Potential impacts of using greywater for domestic irrigation

Abstract

Domestic irrigation using bathroom sourced greywater is an increasingly common practice in Australia. This summary describes a recent study undertaken on a selected range of bathroom products and their potential impacts on soil chemistry and structure when they are present in bathroom greywater. Bathroom greywater is typically a mixture of the more traditional solid soaps, liquid body washes, shampoos and hair conditioners. This study involved the investigation of forty four commercially available bathroom products which included mainstream, generic and "Eco" friendly brands. Simulated shower greywater solutions were prepared for each individual product and these solutions used for both chemical and physical testing. Chemical analysis included the determination of pH, electrical conductivity (EC), sodium, potassium and phosphorus.

Physical analysis involved conducting soil stability tests on three typical Melbourne soil types in order to ascertain any possible impacts on soil structure due to the application of greywater from the bathroom.

Significantly, it was found that as a group, the solid soaps had the most detrimental effect on the soil, with almost total dispersion evident for all products tested. In contrast, the body wash group had a relatively negligible effect on the soils tested which indicated that they were a more sustainable option for the same function. When compared to their mainstream counterparts, products from the "Eco" friendly categories performed no better in either the physical or chemical testing. This study has highlighted the importance of making informed decisions with regard to the most appropriate types of bathroom products that can be used in conjunction with domestic greywater irrigation systems in Melbourne.

Introduction

Australia's prolonged drought has caused communities and industry to rethink some of the wasteful habits which have resulted in the depletion of our increasingly vulnerable fresh water resources. Particularly, with the introduction of strict water restrictions, domestic garden irrigation with household wastewater has become increasingly popular. This wastewater is known as greywater and is so named because of its cloudy appearance and from the fact that it is neither classed as being fresh, nor heavily polluted, such as blackwater (sewage). In a recent guide for environmentally sustainable homes issued by the Department of the Environment, Water Heritage and the Arts, the authors state that reusing greywater outdoors can reduce a household's potable water use by 30 to 50 percent. (S. Fane, 2008). This present investigation examines the suitability of bathroom sourced greywater for domestic garden irrigation. Specifically, this is water that originates from showers, baths, and sinks, which typically produce large quantities of water with relatively small amounts of contaminants and chemicals. This possibly makes bath and shower water the cleanest type of wastewater which can be used for domestic garden irrigation.

Surprisingly, there is very little scientific literature available on the topic of bathroom greywater effects on typical soils in Melbourne. Soil structure is of key importance when considering this issue because of the possible effects that degraded soil structure can have on drainage and in turn destabilisation of typical infrastructures such as foundations, footpaths and driveways. In an attempt to assess the potential for bathroom greywater to cause damage and/or contamination to domestic soils, the investigation involved the preparation of simulated grewywater solutions using a range of products that would be typical components of bathroom greywater. Of particular interest was the amount of sodium present in the compounds tested as this component can be damaging to clays causing them to disperse, resulting in drainage problems as well as crusting (van de Graaff and Patterson, 2001)

Methodology

Product Selection

Early in 2008, the Alternative Technologies Association (ATA) conducted a survey of its members in relation to the types of bathroom products used in their households. All of the forty four products tested in this study were brands identified by ATA members. Product samples used in this study were kindly provided by the ATA.

The survey identified the most popular products from each of four categories: shampoos, conditioners, solid soaps, and body-washes. From these categories, a further distinction was made, according to whether the product was mainstream, generic or "Eco" friendly. The actual brand name of each product is not stated in this report. Each product was assigned a descriptive code for identification purposes and these are listed in Table 1.

Code	Description
BW-O-X	bodywash-organic-number
BW-M-X	bodywash-mainstream-number
C-O-X	conditioner-organic-number
C-M-X	conditioner-mainstream-number
SH-O-X	shampoo-organic-number
SH-M-X	shampoo-mainstream-number
SO-O-X	soap-organic-number
SO-M-X	soap-mainstream-number

Table 1 Codes used to describe products investigated

Determination of a simulated bathroom greywater

In order to simulate typical bathroom greywater compositions, a small sample survey was undertaken. The survey involved interviewing approximately 20 fellow students from the Environmental Science Program at RMIT University with regard to approximate shower times and the amount of bathroom products used during the shower cycle. On the basis of this survey, solutions of 0.5g of product in 200mL of tap water were chosen for use in the physical tests. This concentration was considered to be the worst case scenario and represented the fluxes of higher concentrations of products that would be discharged during use. A more dilute solution was used in the chemical testing.

Physical Testing

Soils containing high proportions of sodium will tend to readily disperse when in contact with water. Dispersion affects drainage and causes erosion and crusting. Slaking is a process that results in the immediate disintegration of soil aggregates when exposed to water and is indicative of a weak soil structure.

The potential impact that each product may have on soil structure was investigated by conducting soil stability tests on three different soil types. The stability tests were undertaken in order to determine whether the soils would disperse or slake when in contact with bathroom greywater.

Soils investigated in this study were chosen because they were representative of light, medium and heavy textured soils sourced from areas of Melbourne. Soil types included a loamy-sand from Melbourne's outer west, a clay loam also from Melbourne's outer west and a heavy clay from Melbourne's north.

Simulated bathroom greywater solutions were applied to petri dishes containing small soil aggregates (approx 2-5mm), and the effects recorded over a 72 hour period.

Chemical analysis

All Chemical analysis was carried out according to standard methods for soil and water Rayment and Higginson (1992)

EC & pH

Excessive amounts of salts, particularly those that contain sodium, have the potential to cause structural degradation in soil. For this reason each of the products were compared by measuring the electrical conductivity (EC) of diluted solutions of each product.

Solutions were prepared, containing 0.1g of product in 200mL of de-ionised water. The EC of each of the solutions was then recorded and from this data, it was possible to assess which of the products had the potential to cause structural damage to the soil.

The pH of each of these solutions was also measured. The pH of greywater containing these products is also another important factor as soil pH can affect plant nutrient uptake as well as impact on structural components of the soil such as the organic matter. The results of the pH and EC analysis are listed in Tables 5 & 6.

Major inorganic components

An initial screening procedure was undertaken in order to identify the major chemical components in the bathroom products. Sample solutions were prepared containing 0.1g of product in 200mL of 2% nitric acid. The sample solutions were then analysed using an Hewlett Packard HP 4500 Series 300 Inductively Coupled Plasma - Mass Seectrometer (ICPMS) in semi-quantitative mode.

It was found that sodium and potassium were the most common cations present in these products; therefore a further investigation was undertaken to quantify these components.

Quantitative analysis of sodium and potassium was conducted using a Varian Spectra Atomic Absorption (AA) 20plus Spectrophotometer. The products were digested prior to analysis in order to remove organic material which would cause interferences or residue build-up in the instrument.

Samples were digested by weighing out 0.5g of each product into 200ml beakers. 20ml of 6M concentrated nitric acid was then added to each beaker. The beakers were then placed on a hot plate and the solutions digested at approximately 100^{o}C until evolution of brown fumes ceased, indicating complete destruction of the organic material in the product. Each digested sample was then transferred into a 200ml volumetric flask and filled to the mark with milli Q water.

Potassium concentrations were then determined quantitatively using Atomic Absorption Spectrophotometry (AAS).

Due to the higher level of sodium in some of the products it was necessary to carry out an additional dilution of the sample digest before analysis.

The available phosphorus levels of the simulated greywater were determined by conventional Spectrophotometric analysis. 0.1g of each product was diluted in 200mL of de-ionised water and the phosphorus concentration determined by generating a colour and measuring the absorbance of the solution at 882nm.

Results

Physical Testing

There was very little difference observed in physical behaviour between simulated greywater solutions and water with the medium and heavy textured soils except for the notable exception of the solid soaps. The light textured sandy soil showed slight dispersion after 24 hours with many of the products with the exception of the mainstream body washes and all of the conditioners. There was slight dispersion of the medium textured soil with one of the organic body washes after 30 minutes. With the exception of one mainstream hard soap, all of the hard soaps showed extensive dispersion after 24 hours. **Figure** 1 illustrates the soil dispersion test results.

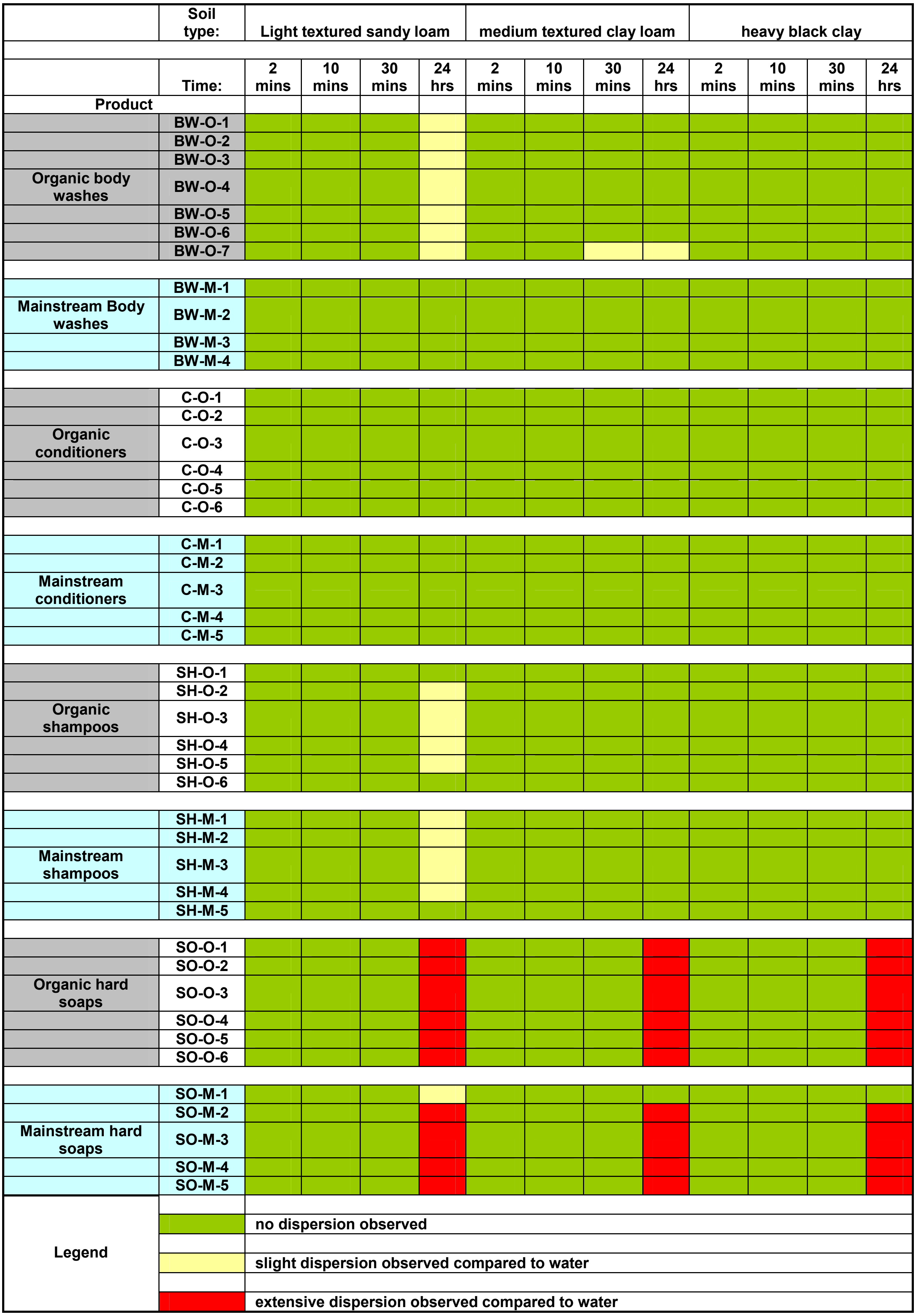

Figure 1 *Soil dispersion test observations for all products and three soil types*

In each case the test solutions were photographed and observed at various time intervals after application of the greywater solution and water control. **Figure 2** illustrates a typical time sequence for an organic soap and a mainstream soap showing extensive dispersion of the soil aggregates in each case. The test solutions are at the top of each image and the water controls are at the bottom in each case.

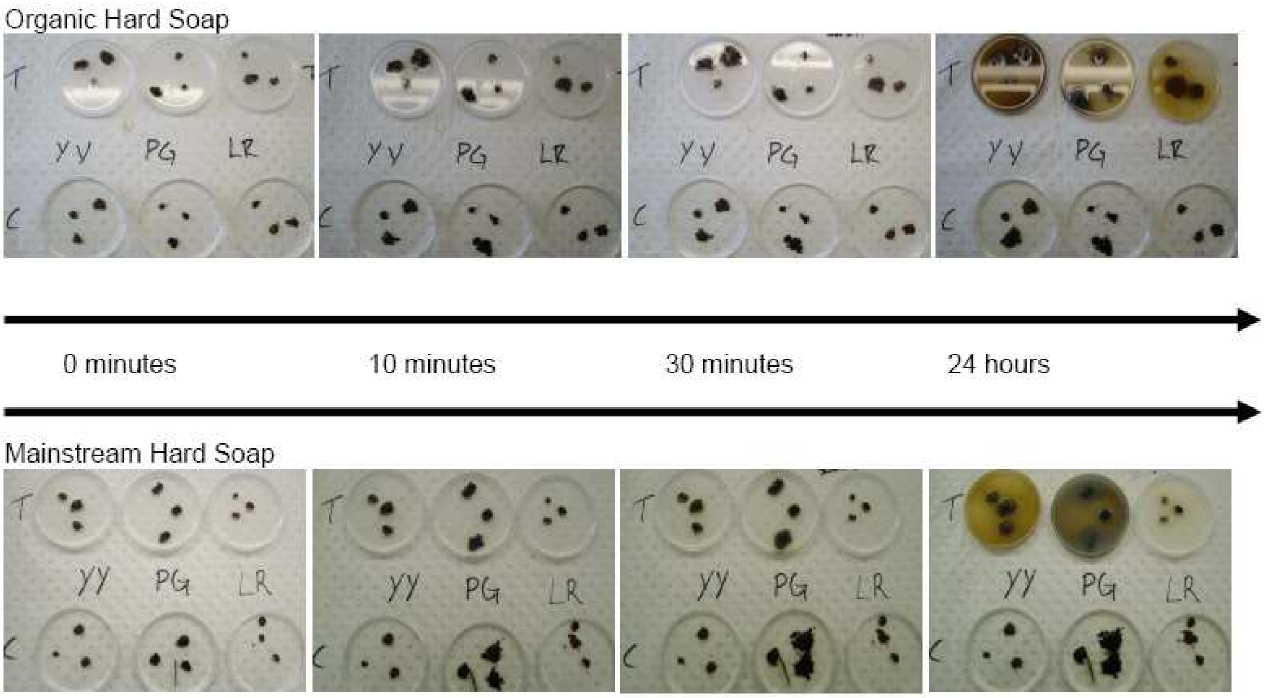

Figure 2 Dispersion test for mainstream and organic hard soaps showing the changes over time

Figure 3 below shows a comparison of the effect of treating soil aggregates with hard soap greywater and body wash greywater. This observation is representative of most of the hard soaps and body washes with the most effect on the light and heavy textured soils.

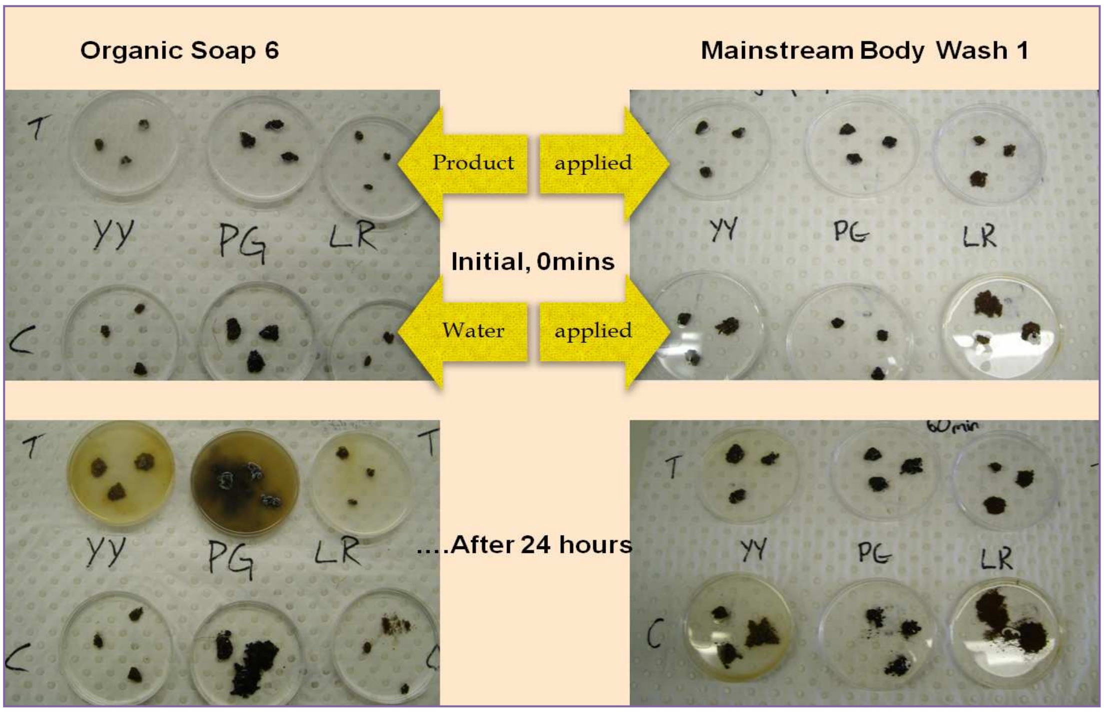

Figure 3 A comparison of the effect of hard soap greywater and body wash greywater on the three soil types

Chemical analysis

EC & pH

The pH of each of the simulated greywater solutions is illustrated in **Figure 5**. The products are grouped together by category. In general the pH of most products was within the 4 to 6.5 range with the exception of the hard soaps which ranged from 7.2 to 9.8. The organic body wash BW-O-7 was found to have a pH well in excess of all of the other body washes.

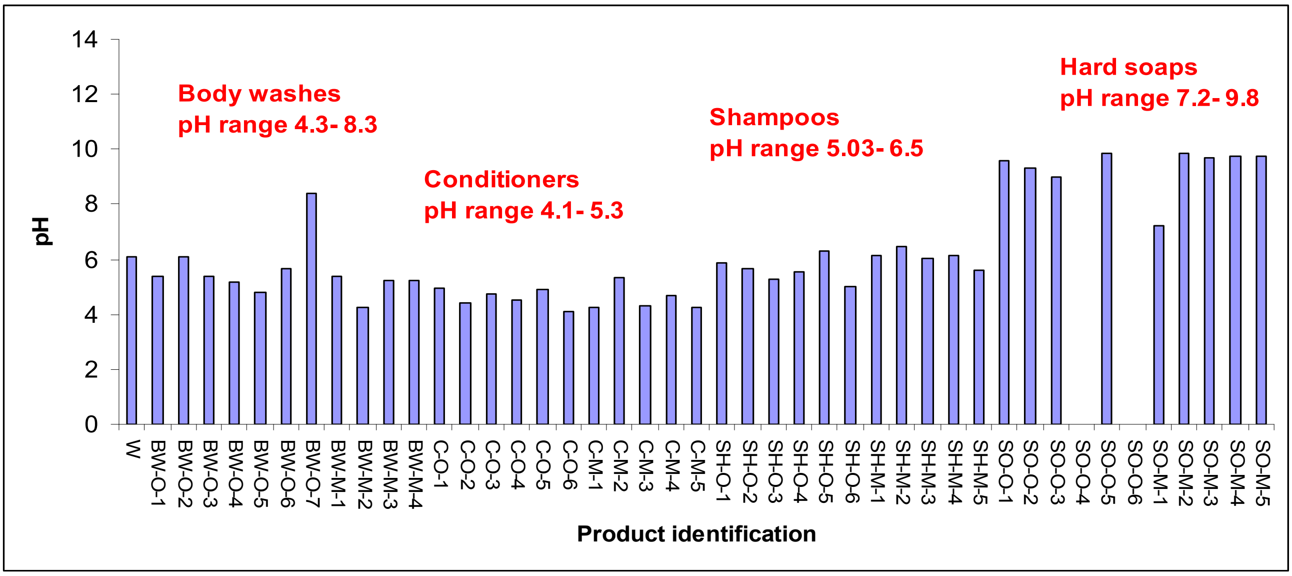

Figure 5 *pH of each product greywater*

The EC of each of the simulated greywater solutions is illustrated in **Figure 6**. The products are grouped together by category. Within each product category there is wide variation in EC with the highest values recorded for the hard soaps and a number of the body washes. The conditioners as a group had the lowest EC values.

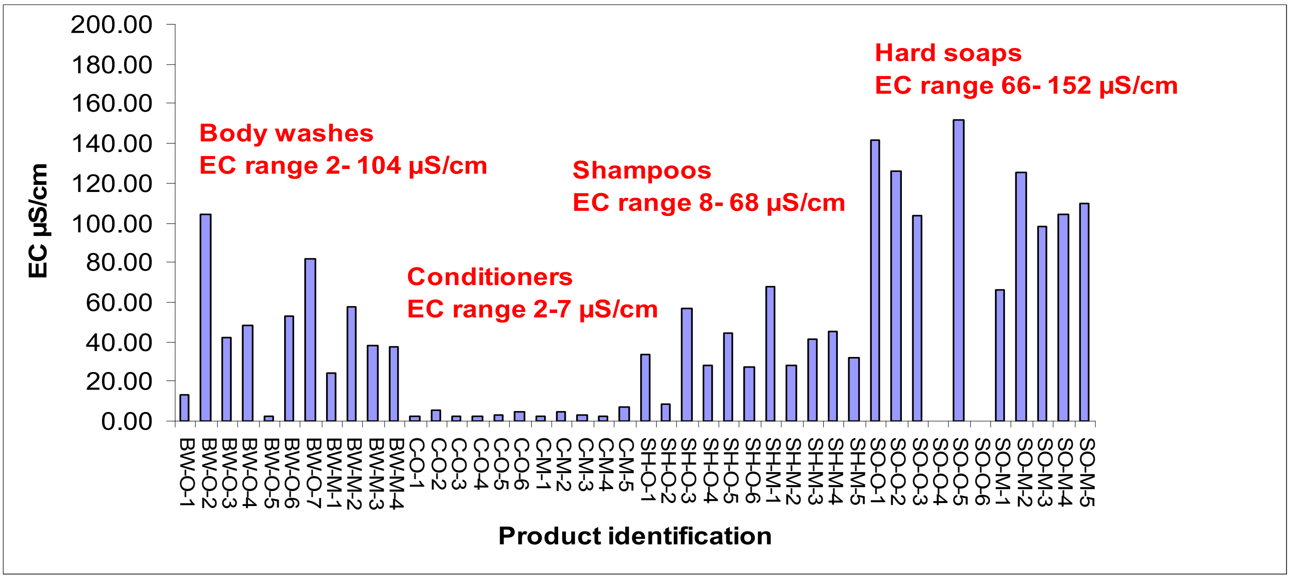

Figure 6 *EC of each product greywater*

Major inorganic components
Semi quantitative ICPMS analysis of the greywater showed that the major component present was sodium and potassium, although boron, magnesium, calcium and zinc were detected in most products. Boron was present in several of the shampoos as well as one of the organic hard soaps. The highest level detected was 0.2ppm in one organic shampoo. The levels of boron in the other greywaters ranged from 0.001 – 0.07 ppm. The highest level of zinc found was in one of the mainstream hard soaps which were known to contain zinc oxide. The zinc level in the greywater was 0.4ppm. The level of zinc in the other greywaters ranged from 0.001 – 0.01 ppm. The levels of magnesium ranged from 0.001- 0.01 ppm and the calcium levels ranged from 0.04- 0.2 ppm. By contrast the sodium levels of the greywaters ranged from 1- 390 ppm and the potassium levels ranged from 0.1- 7ppm. These two components were subsequently analysed quantitatively using AAS. The results for these analyses are illustrated in **Figures 7 & 8.**

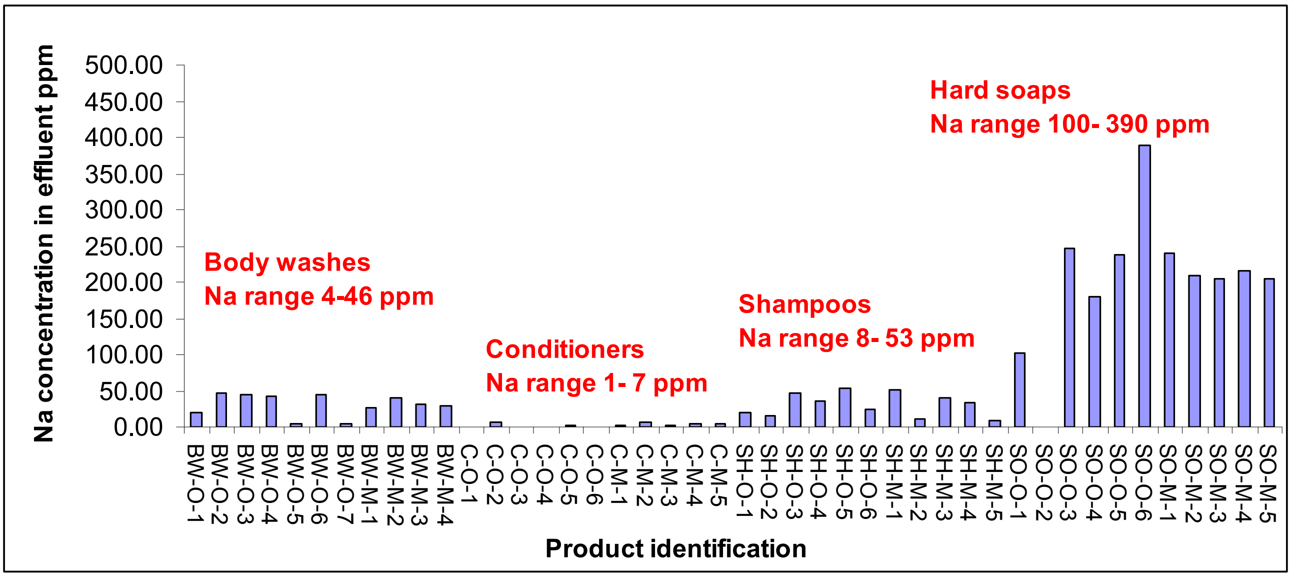

***Figure** 7 Sodium analysis of simulated greywater for each product expressed as ppm sodium*

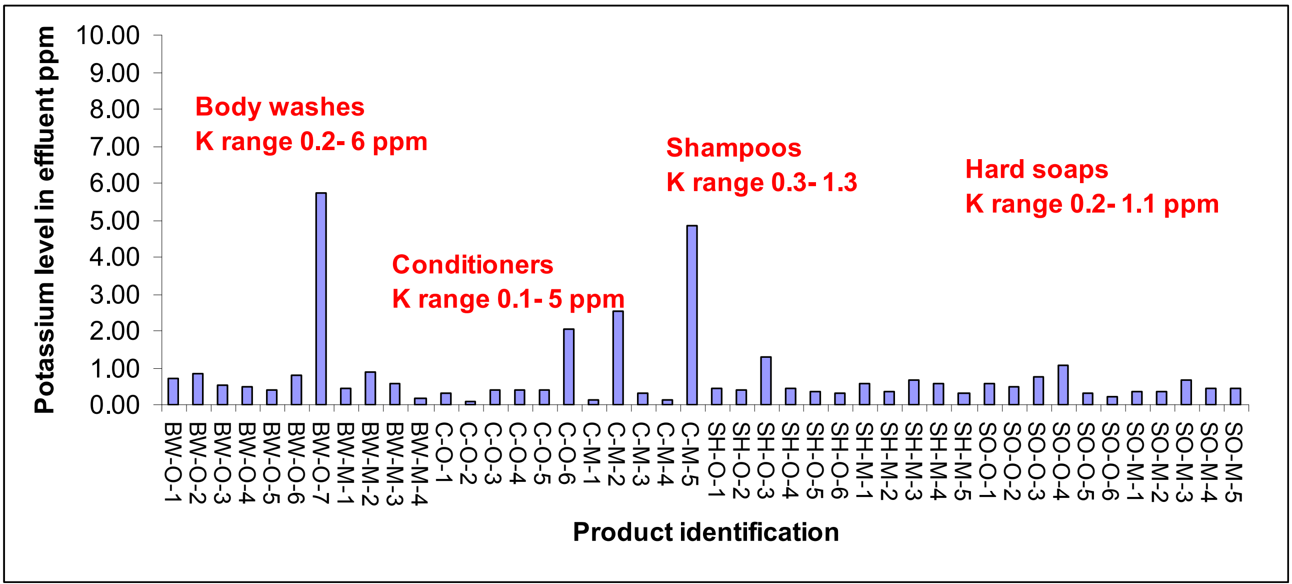

***Figure 8** Potassium analysis of simulated greywater for each product expressed as ppm potassium*

Phosphorus was also determined quantitatively on each greywater using a Spectrohotometric method. The results are illustrated in **Figure 9**. With the notable exception of one mainstream shampoo (with a phosphorus level of 0.23 ppm in the greywater) , the levels of phosphorus were generally less than 0.1ppm in most products and none was detected at all in any of the hard soap greywater.

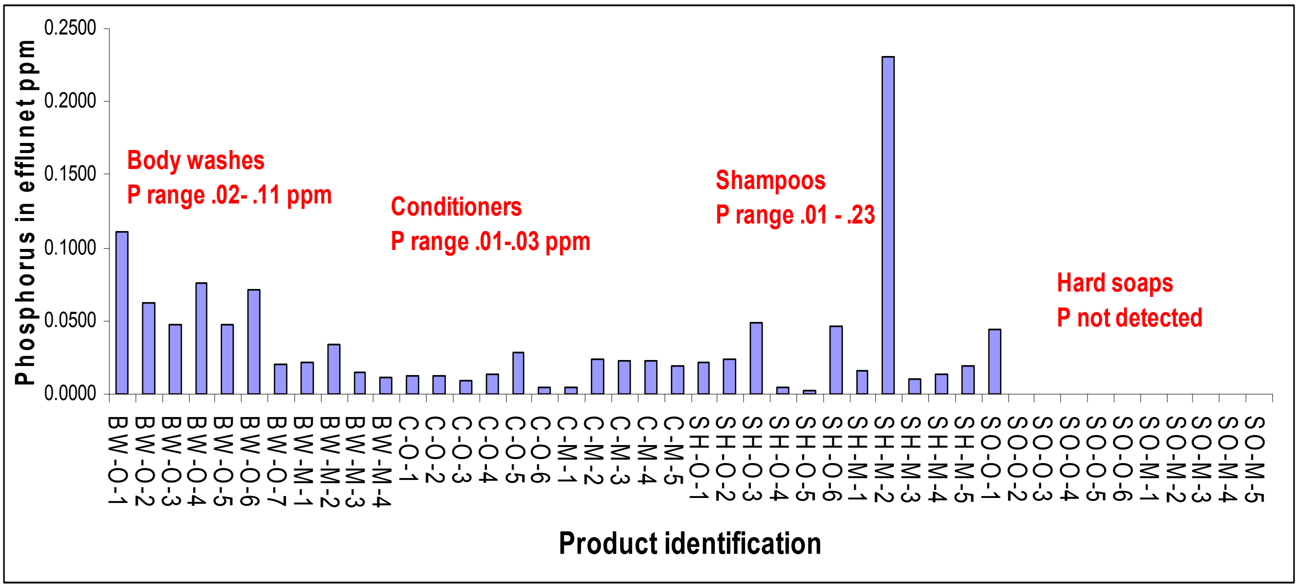

***Figure 9**. Phosphorus analysis of simulated greywater for each product expressed as ppm phosphorus*

Discussion of results

The study has shown that when bathroom greywater is to be used as a source of irrigation water, then the selection of appropriate products is critical. It was found that the effects of greywater on soil will vary depending on the type of soil present. Physical testing of soils showed clearly that most hard soaps produce greywater that is likely to damage soil structure particularly in the case of heavy textured soils and soils with weak structure. It was found that most of the products tested caused dispersion of the clay component in the light textured sandy soil indicating that soils with poor structure, which was the case with this soil, would be particularly vulnerable to greywater that contain damaging components like sodium. Clay dispersion was extensive within 24 hours with most hard soaps tested on each soil type, which indicates that these greywaters would result in poor drainage over time and possible water logging. This in turn could result in damage to foundations in the immediate vicinity or off-site in cases where the irrigated soil is on a slope. On the basis of this very limited sample there was some evidence that the 'eco-friendly' products were more harmful to the soils tested than the mainstream products. This is possibly due to the use of sodium chloride salt in many of these products.

A number of general observations can be made on the basis of the results of chemical testing obtained for the simulated greywater generated by each product.

- Most of the hard soaps tested produced high pH greywater which over time could be damaging to plants and soil
- Most of the conditioners produced low pH greywater but as these products are used in conjunction with shampoos with higher overall pH, use of these products would probably not alter soil pH
- Body washes appeared to pose no long term problems associated with soil pH
- The EC of the hard soap greywater was found to be higher than all other products tested but not excessive and unlikely to pose long term problems associated with induced salinity.

However the sodium level of all of these products is very high and poses a 'sodium hazard' to clay soils over time – this is supported by the soil stability results obtained in this study which showed that most of the hard soaps caused extensive dispersion of all the soils tested

- The sodium level of most of the body washes tested was relatively low indicating that these products should be used in preference to hard soaps – the products with lower sodium content being preferred.
- The sodium level of most shampoos and conditioners was low although the long term effects of some of the shampoos would need to be investigated further as low sodium content greywater can still cause long-term problems if the levels of other captions such as calcium and magnesium are low (van de Graaff and Patterson, 2001) This also applies to the body washes.
- The levels of potassium found for most products would appear to provide a source of potassic fertiliser and not pose any long term problems associated with nutrient buildup
- The levels of zinc in one of the hard soaps could pose long term problems of zinc accumulation in the receiving soil
- Most of the products tested produced greywater with low phosphorus levels although one mainstream shampoo could pose problems long term depending on the receiving location and topography
- There was no indication the so called 'eco- friendly' products were more suitable for greywater irrigation systems than mainstream products.

In summary this investigation has shown that the choice of bathroom products for use in greywater irrigation systems is important to prevent chemical and structural deterioration of receiving soils. Products with high sodium levels should be avoided due to their destructive effects on clay soils. The investigation has also demonstrated that considerably more research needs to be undertaken on a much larger range of bathroom products to enable informed advice to be given on best practice bathroom greywater irrigation.

References

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