Applied Soil Ecology 72 (2013) 195–202

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

# Impacts of standard and 'low environmental impact' greywater irrigation on soil and plant nutrients and ecology

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ARTICLE INFO

*Article history:*
Received 8 February 2013
Received in revised form 1 July 2013
Accepted 12 July 2013

*Keywords:*
Earthworm
Ecotoxicology
Greywater
Plant nutrition
Salinity
Wastewater

ABSTRACT

Interest in recycling greywaters is increasing as population growth, pollution and climate change increase pressure on water resources. There has been little research investigating impacts of irrigating untreated greywater on soil and plant health and to our knowledge no studies comparing greywater from standard with "low environmental impact" detergents. A soil-pot trial with lettuce and radish compared tap water, nutrient solution, and grey water (standard and minimal impact) irrigation. Greywater had impacts on plant biomass and nutrition, soil enzyme activity, and worm avoidance. In particular, there was little indication that the minimal impact greywater was safer for irrigation than the standard greywater. The minimal impact greywater was the only greywater treatment to have a significant negative impact on soil phosphatase activity and worm avoidance. The results highlight the need for greater understanding of the impacts of untreated greywater in irrigating vegetable gardens and especially when manufacturers make claims about the environmental friendliness of their products.



## 1. Introduction

Population growth, pollution and climate change are placing increasing pressure on water resources across the globe. In many regions, including Australia, the USA and the Middle East, there is a high level of interest in recycling greywaters. The potential for recycling greywater (laundry, non-toilet bathroom and sometimes kitchen waste water) has received considerable attention because greywater generally has fewer pathogens and pollutants than combined municipal water (i.e. public water supply) that also contains sewage (Eriksson et al., 2002). In addition, greywater typically makes up 45–75% of household waste water production (Christova-Boal et al., 1996; Ghisi and de Oliveira, 2007; Mandal et al., 2011) thus reuse provides significant potential for reducing overall household water usage.

Research generally recommends that only treated greywater is used on gardens as, in particular, this reduces risk from microbial contamination (Maimon et al., 2010). However, as competition for other water resources has increased, some jurisdications now allow the direct use of untreated greywater on gardens, including in some circumstances on food plants (e.g. ADEQ, 2011; EPA Victoria, 2008). In addition, where water is scarce and/or water restrictions tight it is likely that individual householders may use untreated greywater on their gardens irrespective of regulations, guidelines and safety (Maimon et al., 2010). Provided the risks can be managed, the use of greywater has cost advantages over other water recycling options for residential areas, such as the use of treated effluents, as it is relatively inexpensive to implement at an individual household scale (i.e. little infrastructure is required).

A number of studies have investigated the impacts of untreated greywater usage on pathogen and standard water quality parameters (e.g. chemical oxygen demand) with fewer studies looking at soil and plant health (Chaillou et al., 2011; Mandal et al., 2011; Negahban-Azar et al., 2012; Pandey et al., 2011; Rodda et al., 2011). Where soil and plant health studies have occurred they have tended to concentrate on a narrow range of traditional parameters such as plant yield, pH, electrical conductivity and major nutrients (Pandey et al., 2011; Pinto et al., 2010). There has been particularly little research investigating the impacts of greywater on trace elements (except B) in plants or soil (Misra et al., 2010; Rodda et al., 2011) and on soil ecotoxicology. While pathogen and standard water parameters are highly important concerns it is also important to ensure that the lack of information on potential environmental impacts is resolved so that greywater is not used inappropriately.

In addition, detergent manufacturers are now releasing products specifically designed to have lower environmental impacts and be safer for irrigation puposes than conventional detergents

*Abbreviations:* ECEC, effective cation exchange capacity; ICP-OES, inductively coupled plasma optical emission spectrometer; NR, net avoidance; PAR, photosynthetically active radiation; THAM, tris(hydroxymethyl)aminomethane.

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http://dx.doi.org/10.1016/j.apsoil.2013.07.012

**Table 1**
General characteristics of the topsoil used in the pot trial.

| | |
|---|---|
| Texture (USDA) | Sandy loam |
| Particle size analysis (USDA) | 10% clay (<2 μm), 14% silt (2–50 μm), 76% sand (>50 μm) |
| Bulk density | 1.26 tonne $m^{-3}$ |
| Moisture characteristics | Field capacity (−33 J $kg^{-1}$) 16%, permanent wilting point (−1500 J $kg^{-1}$) 6% |
| pH (1:5 soil:$H_2O$) | 7.7 |
| Electrical conductivity (1:5 soil:$H_2O$) | 76.1 μS $cm^{-1}$ |
| Cation exchange capacity | 8.53 cmol $kg^{-1}$ |

(e.g. Planet Ark, 2008). As such, there is a need to compare the efficacy and environmental safety of the newer detergents with more traditonal detergents for use in grey water irrigation on gardens. To the authors' knowledge these comparisons have yet to occur.

The current study investigated the impact of two laundry greywaters (a conventional detergent and a detergent marketed as "minimal environmental impact" and "garden safe" (Planet Ark, 2008)) compared with tap water and a nutrient solution. The impacts of the irrigation treatments were tested on soil and plant health including plant growth, macro and trace elements, pH, electrical conductivity and ecotoxicological indicators.

## 2. Materials and methods

The trial was conducted between August and October 2010 as a pot-based experiment under open field conditions in a garden in suburban Melbourne, Australia (37°51′ S, 144°53′ E). Forty black plastic pots (1.5 L) were each filled with 1.7 kg of sandy loam topsoil (Table 1) and lightly tamped down. Prior to being filled with soil, two layers of paper towel were placed in the bottom of each pot to prevent soil escaping from the drainage holes. The pots were free draining to reduce potential concentration of salts during the trial.

Lettuce (*Lactuca sativa* L. cv. Iceberg) seedlings from a local nursery were sown into 20 pots at a rate of two plants per pot. Radish (*Raphinus sativus* L. cv. French breakfast) seeds were sown into the remaining 20 pots at a rate of 10 seeds per pot. Lettuce and radish were chosen due to both species being common plants grown in home vegetable gardens. On Day 22 each pot was thinned to 4 radish seedlings by removing the biggest and smallest seedlings within each pot.

Immediately after planting/sowing all pots were irrigated with tap water from the reticulated municipal water supply until the soil was thoroughly moistened and excess water was draining from the bottom of the pots. On Days 2 and 3 all pots were irrigated with 100 mL of nutrient solution (1/4 strength Aquasol, Hortico, Table 2). Thereafter, each pot was watered daily with 100 mL of one of four irrigation treatments: tap water, nutrient solution (1/4 strength Aquasol, Hortico), greywater from standard laundry detergent (Fab front loader and HE top loader 2× ultra concentrate sunshine fresh, Colgate-Palmolive) (hereafter referred to as "standard grey"), greywater from low environmental impact laundry detergent (Aware Sensitive Skin, Planet Ark) (hereafter referred to as "eco grey") (Table 2). On Days 8, 15, 22, 25, 29, 37 and 52 instead of the standard treatment, the tap water and greywater treatments were irrigated with 100 mL of the nutrient solution and the nutrient solution treatments were irrigated with 100 mL of tap water. The pots were not irrigated on Days 14, 50 and 51 due to there being adequate water from rainfall.

Greywater was sourced from a suburban home in Melbourne, Australia. The household had two adults and no children. Greywater was produced by washing mixed clothing in a Simpson esprit 5 kg capacity front loading washing machine (45S508D) on a 30 °C cotton/colours wash. The detergent (standard grey or eco grey) was added at the manufacturers' instructions.

The trial was a full factorial completely randomised block design (2 plant species × 4 watering regimes × 5 replicates). Every 14 days each block of plots was moved to the position of the next block in the cycle and the pots within in each block were re-randomised. This aimed to minimise any environmental variation (for example in the amount of photosynthetically active radiation, PAR) experienced by plants during the experiment.

A number of measurements were taken during the experiment. Irrigation waters were sampled weekly and analysed for a suite of chemical characteristics including pH and electrical conductivity (see Table 2 for full listing). Daily measurements were taken of rainfall and temperature (maximum and minimum). A light metre (Li-Cor Quantum/Radiometer/Photomoter Model LI-189) was used to measure representative PAR above the plants during the experiment.

On Day 55 soil for the enzyme assays was collected. Approximately 1 cm of the soil surface was removed from a small area of the pot before half filling a 70 mL collection tube with soil at field moisture. The soil was stored in sealed plastic containers at 4 °C until analysed for alkaline phosphatase and urease activity. Alkaline phosphatase (E.C 3.1.3) (buffered to pH 11) was determined according to the methods described in Tabatabai (1994). However, instead of using 50 mL Erlenmeyer flasks the assays were conducted using 15 mL plastic centrifuge tubes with the contents mixed on a vortex for 10–15 s. The samples were incubated at 22 °C for 2 h. Colour development in the samples was determined by transferring 300 μL aliquots of clear supernatant into 96-well microplates and measuring absorbance at 400 nm using a microplate reader (UVM340, ASYS Hitech GmbH, Nordstrasse, Eugendorf). Enzyme activity was expressed as μg p-nitrophenol/g dry soil/h, adjusted for the background absorbance of a negative control sample. The urease (EC 3.5.1.5) (buffered to pH 9) assay was based on the methods described by Tabatabai (1994) and Sinsabaugh et al. (2000). Nine milliliters of tris(hydroxymethyl)aminomethane (THAM) buffer (0.1 M, pH 9) and 1 mL of 200 mM urea was added to 1 g (dry weight equivalent) of soil in a 15 mL centrifuge tube and vortexed for 10–15 s. The samples were incubated for 24 h at 22 °C after which time they were chilled and then centrifuged to stop the reaction. Negative control samples were prepared by mixing 1 g soil with 10 mL of THAM buffer which were then processed in the same manner as the other samples and duplicate substrate controls (9 mL of THAM buffer and 1 mL of 200 mM urea). Duplicate 200 μL aliquots of clear supernatant were then transferred into a 96-well microplate. The concentration of ammonium released was measured colorimetrically based on the method described by Sinsabaugh et al. (2000) using salicylate and cyanurate reagent packets (Hach Company, Loveland, CO, USA) and measuring absorbance at 610 nm using a microplate reader. Urease activity was expressed as μg/$NH_4$ produced/g dry soil/h, adjusted for absorbance of the negative and substrate.

The trial was harvested on Day 57. Lettuce and radish shoots were harvested by cutting the shoots at ground level with clean scissors. Radish roots were harvested by gently removing the roots from the soil so as to minimise any damage to the root system. Shoots and roots were rinsed sequentially in 2% Decon 90 (Decon Laboratories Limited, East Sussex, United Kingdom) in tap-water, 2 by tap-water only rinses and a final deionised water rinse. Cleaned shoots and roots were placed in paper bags and dried at 70 ± 10 °C for 48 h before being ground to <2 mm. Ground plant samples were analysed for C, N and S by a LECO CNS2000 analyser and microwave digested in 70% $HNO_3$ before elemental analysis by inductively coupled plasma optical emission spectrometer (ICP-OES) for P, K, Ca, Mg, Na, Fe, Zn, Cu, Mn, B and Mo. Where there was not enough sample for both sets of chemical analyses, the tissue was only analysed by ICP-OES.