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Research article

# Irrigated greywater in an urban sub-division as a potential source of metals to soil, groundwater and surface water

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## ABSTRACT

Increased water demands in dry countries such as Australia, have led to increased adoption of various water reuse practices. Irrigation of greywater (all water discharged from the bathrooms, laundry and kitchen apart from toilet waste) is seen as a potential means of easing water demands; however, there is limited knowledge of how greywater irrigation impacts terrestrial and aquatic environments. This study compared four greywater irrigated residential lots to adjacent non-irrigated lots that acted as controls. Accumulation and potential impacts of metals in soil, groundwater and surface water, as a result of greywater irrigation, were assessed by comparing measured concentrations to national and international guidelines. Greywater increased concentrations of some metals in irrigated soil and resulted in As, B, Cr and Cu exceeding guidelines after only four years of irrigation. Movement of metals from the irrigation areas resulted in metal concentrations in groundwater (Al, As, Cr, Cu, Fe, Mn, Ni and Zn) and surface water (Cu, Fe and Zn) exceeding environmental quality guidelines again within four years. These results are unlikely to be universally applicable but indicate the need to consider metals in greywater in order to minimize potential adverse environmental effects from greywater irrigation.

## 1. Introduction

Water scarcity is a problem worldwide (Jury and Vaux, 2007; Godfrey et al., 2009). Reuse of greywater has been advocated as one potential solution (Eriksson et al., 2002; Winward et al., 2008; Eriksson and Donner, 2009; Maimon et al., 2010; Zhu et al., 2015). Greywater is wastewater and is typically generated from laundries, bathrooms (showers baths and hand sinks) (Christova-Boal et al., 1996; Eriksson et al., 2002) and sometimes includes kitchen wastewater (sinks and dishwashers) (Nolde, 2000; Friedler, 2004; Maimon et al., 2010), but does not include wastewater generated by toilets (i.e., black-water). Greywater reuse typically occurs via irrigation (Wiel-Shafran et al., 2006; Howard et al., 2007; Travis et al., 2010) although other uses, such as flushing toilets, are becoming more common (Jeppesen, 1996; Godfrey et al., 2009; March and Gual, 2009; Etchepare and van der Hoek, 2015). Despite widespread adoption of the reuse of greywater for irrigation, there is limited research on the impacts of this wastewater on the receiving environment (Donner et al., 2010; Stevens et al., 2011; Turner et al., 2013; Reichman and Wightwick, 2013).

The environmental sustainability of greywater irrigation has been questioned as greywater contains contaminants such as nutrients, cations and anions (e.g., Wiel-Shafran et al., 2006; Turner et al., 2013) and metals (Eriksson and Donner, 2009). Metals in greywater can originate from the source water (Huston, 2010), plumbing (Eriksson and Donner, 2009), household products, household appliances and personal care products (Gray and

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Becker, 2002; Diaper et al., 2008; Tjandraatmadja et al., 2008; Ayenimo et al., 2010). Tjandraatmadja et al. (2008) investigated the presence of As, B, Cd, Cu, Fe, Pb, Ni, Sn and Zn in a range of household and personal care products and found that Fe and Zn were present in the majority of products, B was present in a large range of products (laundry, kitchen and bathroom) and traces of Pb and Ni were also in many products.

Although the potential risks posed by nutrients and salts are commonly addressed in Australian federal and state government guidelines (e.g., ACT Health, 2007 and DoEUS NSW, 2008), the potential hazards posed by metals (Förstner and Wittmann, 2012) in greywater are inadequately addressed. Water quality guidelines for greywater exist in Australia (e.g., EPHC, 2006), but few guidelines are available for metals and those that are included are often derived from a limited dataset (Eriksson et al., 2006; Revitt et al., 2011; Turner et al., 2013). The guidelines for metals that do exist are based on drinking water quality guidelines and irrigation guidelines taken from ANZECC and ARMCANZ (2000). These irrigation guidelines have been developed for the protection of agricultural crops and are not based on ecological considerations. Minimal research has been published assessing metals in greywater and their environmental impacts (Eriksson and Donner, 2009; Reichman and Wightwick, 2013) and no single study has assessed the impacts of metals from greywater irrigation in three connected environmental compartments: soil; groundwater; and surface water (Fig. 1).

Understanding the transport of metals from greywater irrigation in compartments of the environment is important as metals are highly persistent in the environment and some are toxic (Bryan and Langston, 1992; Facchinelli et al., 2001; Rattan et al., 2005; Peralta-Videa et al., 2009). Metal adsorption to soils is complex (Bradl, 2004) and desorption can lead to off-site transport of metals via leaching (Schmidt, 2003) resulting in contamination of groundwater (Rattan et al., 2005) and surface water by leachate. Erosion of contaminated soils, can also result in contamination of surface waterways (Zhong et al., 2015).

It is important that robust government environment regulation and policy is underpinned by sound science. Chartres (2006) emphasized that water resources management policy should not be made without sound evidence – unfortunately this is not always possible. For example, during the Australian millennium drought (late 1996 to mid-2010), water saving policy, including greywater reuse, was urgently needed; however, targeted science supporting greywater reuse and its impacts on the environment was not available. Consequently, in Queensland, and other Australian states, the next best underpinning science (onsite sewerage guidelines (e.g. DIP, 2007)) was used.

The aim of this study was to determine whether metals in greywater that was irrigated to soil could lead to elevated concentrations of metals in soils, groundwater and adjacent surface water. Therefore, this study:

1. assessed the metal composition of the source water and greywater from four households;
2. compared metal concentrations in greywater irrigated soil to those in adjacent non-irrigated soils (controls);
3. compared soil metal concentrations in irrigated soils to national and international soil contaminant guidelines;
4. assessed the transportation of metals from greywater; and
5. compared metal concentrations in groundwater and surface water to national and international contaminant guidelines.

## 2. Methods

### 2.1. Research design

The design of this study included the collection and analysis of the following samples for metals:

- greywater;
- soil from four residential urban lots irrigated with greywater and from four adjacent vacant non-irrigated lots (controls);

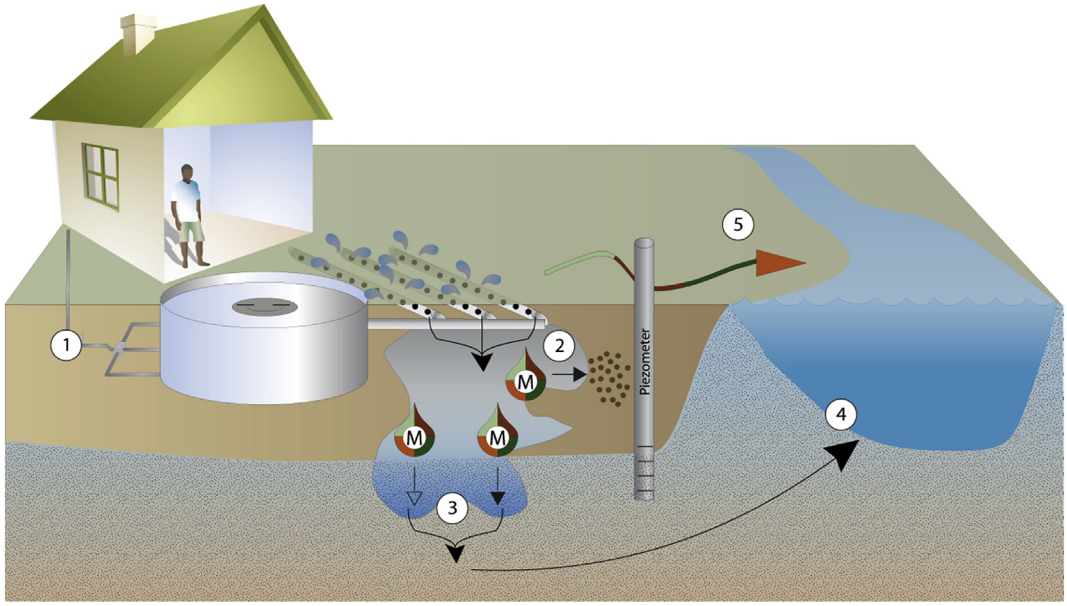

**Fig. 1.** Conceptual diagram of greywater irrigation and metal movement; Household sources of metals ① stored in a concrete tank then distributed via greywater sub-surface irrigation ● resulting in direct ● and indirect ● metal transportation (metal soil adsorption - direct ②; metal leaching - direct and indirect ③); lateral movement of contaminated groundwater to surface water ④; and surface runoff with soil erosion - (not assessed in this study ⑤) and the impacts in three connected environmental compartments: soil ●; groundwater ● (via sampling at the piezometer(s); and surface water.●