ENVIRONMENTAL IMPACTS OF GREYWATER USE FOR IRRIGATION ON HOME GARDENS

By

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This thesis is presented for the degree of Doctor of Philosophy,

Murdoch University, Western Australia

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DECLARATION

I declare that this thesis is my own account of my research and contains as its main content, which has not previously submitted for a degree at any tertiary education institution.

Radin Maya Saphira bte Radin Mohamed
LIST OF PUBLICATIONS

Paper presented at conferences:


Journals:


Socrates said unexamined life is not worth living. But the over examined life makes you wish you were dead. This was one of the reasons why I undertook the decision years ago. Which I believe, given the alternative, I’d rather be living.

I’m most grateful to many people who assisted me in the completion of this thesis.

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ABSTRACT

This study focuses on the feasibility and environmental impacts of using raw domestic greywater from laundry and bathroom after only primary treatment, e.g. coarse filtration for irrigating lawns and gardens. The use of greywater for landscape irrigation requires careful management, especially in regions with sandy soils and shallow groundwater levels. There is the possibility that excessive nutrients and other contaminants will leach into surrounding water bodies. This has been a major concern with greywater use in ecologically sensitive environments, such as on the Swan Coastal Plain of Perth, Western Australia. Proper management is essential to ensure environmental risks from greywater irrigation are avoided.

The main purpose of the first stage of the study was to develop a new zero-tension lysimeter (ZTL) as a leachate sampler in a greywater irrigation plot. The new ZTLs were tested to compare the quantity and quality of leachate collected with that from the conventional pan lysimeter, in a pilot-scale study. The results indicate that the new lysimeter designated as ZTL (N1), was effective at collecting leachate and was suitable to install at household sites. The lysimeter ZTL (N1) design offers significantly improved performance, was cost-effective and required limited effort to install using an auger, which also minimizes soil disturbance. Since the lysimeter was practical and inexpensive it was established to facilitate the monitoring of greywater irrigation.

The second stage of the study was to monitor the use of primarily treated greywater by using diversion system from bathrooms and laundries at four Perth houses: two houses at the Bridgewater Lifestyle Village (BWLV), one each at White Gum Valley and Hamilton Hill. Each house had different characteristics: different house types, occupants, cleaning product preferences and presence, or not, of household pets. Water use activities, soil and vegetation were monitored and were sampled for physical and chemical characteristics. Groundwater samples at the BWLV site were also collected. This site has 389 houses with a greywater
A diversion system installed in each, is located close to the Peel-Harvey estuary and a wetland, and has a shallow aquifer. Monitoring results showed that the groundwater samples were within the ANZECC guidelines. Greywater quality showed high variability depending on water consumption by washing machines, use of detergents and fabric softeners, as well as individual lifestyles. Land activities such as fertilizers and pets were expected to contribute to high amounts of nutrients in the leachate. Mulching and fertilizer used by householders in conjunction with greywater irrigation improved the function of soil and condition of plants.

The third stage of the study was to determine the effects of raw laundry and bathtub greywater irrigation on the growth of couch grass (*Cynodon dactylon* L.) sod on a sandy soil in a 24-week study, from October 2009 to March 2010. In Perth, the use of greywater is significant during these months as rainfall is at its lowest and irrigation demand at its highest. Couch grass is a common lawn used in Western Australia with excellent drought tolerance, water efficiency and relatively low maintenance requirements. Three irrigation treatments were applied using a modified aquarium tank: (i) 100% scheme water as a control (TW), (ii) untreated full cycle laundry water (LGW), (iii) untreated bathtub water (BGW). Salts and nutrients Na, Cl, P, Ca, Mg, K, B, Zn and Al were chosen for measuring because they are dominant constituents in greywater and have a beneficial role in turf grass growth. Their dynamics and mass balance were assessed by measuring the irrigation (input) and leachate (output) volumes and concentrations of element concentration in both input and output water of the tank. Irrigation using LGW and BGW in sand resulted significant leaching of some Mg and Al beyond the 30cm root-zone depth. The mass balance showed an increased amount of stored Na, Cl, P and K in the soil at the end of the study. The accumulation of salts and nutrients in the soil has resulted in the infiltration rate, $K$, gradually declining.

The final stage of the study was to investigate further the significant reduction of $K$ in the tank test. Another soil hydraulic property, capillary rise ($P_c$), was also measured. The soil samples were collected from greywater-irrigated plots at the case studies and the tank test, as mentioned previously. In addition, the study
examined the changes in soil properties from the use of an anionic surfactant, *linear alkylbenzene sulphonate* (LAS) which is known to be the main ingredient in detergent formulation. A commercially available surfactant-based wetting agent to alleviate water repellency in household gardens was also considered. Irrigation with raw laundry and bathtub greywater, application of LAS and a wetting agent made a significant reduction on infiltration rate, $K$, and on $P_c$. At the case study sites, the changes were difficult to quantify owing to various land activities that influenced the result.

The results of the extensive experimental on-site program indicated that the use of primarily treated greywater is a viable option to conserve water for irrigation during times of drought and water restrictions. The sustainable use of raw greywater would vary with specific site conditions and householder practices. Soil and plant quality parameters are significantly affected after continuous irrigation with greywater. This is mainly determined by the management regime of greywater irrigation and its composition. In addition, continuous irrigation with greywater may lead to accumulation of salts, plant nutrients and some nutrients beyond plant tolerance levels. Therefore, these concerns should be essential components of any management plan for greywater irrigation. On the other hand, plant growth, soil fertility and productivity can be enhanced with properly managed greywater irrigation, through increasing levels of plant nutrients and soil organic matter. It is suggested that proper management of greywater irrigation with periodic monitoring of soil fertility and quality parameters are required to ensure successful and safe long-term use of greywater for irrigation. The adequate assessment of any environmental risks will require further research.
<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>ANZECC</td>
<td>Australian and New Zealand Environment Conservation Council</td>
</tr>
<tr>
<td>ARMCANZ</td>
<td>Agriculture and Resource Management Council of Australia and New Zealand</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>B</td>
<td>Boron</td>
</tr>
<tr>
<td>BGW</td>
<td>Bathtub greywater</td>
</tr>
<tr>
<td>BOM</td>
<td>Bureau of Meteorology, Australia</td>
</tr>
<tr>
<td>Ca, Ca$^{2+}$</td>
<td>Calcium, calcium ion</td>
</tr>
<tr>
<td>CA</td>
<td>California</td>
</tr>
<tr>
<td>Cl, Cl$^{-}$</td>
<td>Chloride, chloride ion</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>DOH</td>
<td>Department of Health</td>
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<tr>
<td>EC</td>
<td>Electrical conductivity</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>ETC</td>
<td>Environmental Technology Centre</td>
</tr>
<tr>
<td>Fe</td>
<td>Ferum or iron</td>
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<tr>
<td>GDD</td>
<td>Greywater Diversion Devices</td>
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<td>GTS</td>
<td>Greywater Treatment System</td>
</tr>
<tr>
<td>ICP-AES</td>
<td>Inductively coupled plasma-atomic emission spectroscopy</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>K</td>
<td>Infiltration rate</td>
</tr>
<tr>
<td>LGW</td>
<td>Laundry greywater</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
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Na, Na⁺  Sodium, sodium ion
NATA  National Association of Testing Authorities, Australia
NH₄⁺, NH₄⁺  Ammonium, ammonium ion
NO₃⁻, NO₃⁻  Nitrate, nitrate ion
NO₂⁻, NO₂⁻  Nitrite, nitrite ion
PO₄⁻, PO₄³⁻  Phosphate, phosphate ion
SAR  Sodium Adsorption Ratio
SE  Standard Error
SO₄²⁻  Sulphate ion
TDS  Total Dissolved Solids
TL  Tension Lysimeter
TN  Total Nitrogen
TSS  Total Suspended Solids
TW  Tap water from scheme water supply
UAE  United Arab Emirates
US  United States of America
USEPA  United States Environmental Protection Agency
UK  United Kingdom
WA  Western Australia
WHO  World Health Organisation
ZTL  Zero-tension lysimeter
ZTLP  Zero-tension lysimeter pan
ZTL (N1)  Zero-tension lysimeter (new 1)
ZTL (N2)  Zero-tension lysimeter (new 2)
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