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Designing living walls for greywater treatment

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ABSTRACT

Greywater is being increasingly used as an alternative water source to reduce potable water demand and to alleviate pressure on sewerage systems. This paper presents the development of a low energy and low maintenance greywater treatment technology: a living wall system, employing ornamental plants (including vines) grown in a sand filter on a side of a building to treat shower, bath, and washing basin wastewaters. The system can, at the same time, provide critical amenity and micro-climate benefits to our cities. A large scale column study was conducted in Melbourne, Australia, to investigate the following design and operational factors of the proposed system: plant species, saturated zone design, rest period, hydraulic loading rate and pollutant inflow concentration. The results indicate that the use of ornamental species (e.g. *Canna lilies*, *Lonicera japonica*, ornamental grape vine) can contribute to pollutant removal. Vegetation selection was found to be particularly important for nutrient removal. While a wider range of tested plant species was effective for nitrogen removal (>80%), phosphorus removal was more variable (−13% to 99%) over the study period, with only a few tested plants being effective - *Carex appressa* and *Canna lilies* were the best performers. It was also found that phosphorus removal can be compromised over the longer term as a result of leaching. Excellent suspended solids and organics removal efficiencies can be generally achieved in these systems (>80% for TSS and >90% for BOD) with plants having a relatively small impact. Columns had an acceptable infiltration capacity after one year of operation. When planted with effective species (e.g. *Carex appressa* and *Canna lilies*), it is expected that performance will not be significantly affected by longer rest periods and higher pollutant concentrations in the early years of system operation. The results of this study, thus, demonstrate that innovative and aesthetically pleasing living walls can be designed for treatment of greywater at the household scale.

1. Introduction

Growing urban population coupled with degrading quality and quantity of freshwater resources is shifting the way urban water is managed with the use of alternative water sources to meet demand (Bahri, 2012). Light greywater, that is wastewater discharges from showers, baths and washing basins, represents an attractive alternative water source for non-potable uses. For instance, potential savings of 9–46% can be achieved from greywater recycling (Boyjoo et al., 2013). Since light greywater is the least polluted wastewater stream (Eriksson et al., 2002), it requires minimum treatment which increases its suitability for on-site treatment and re-use schemes.

Technologies that currently exist for on-site greywater treatment include sand filters, fixed film reactors, rotating biological reactors, membrane bioreactors, sequencing batch reactor and wetland systems (Pidou et al., 2007; Li et al., 2009). Yet, greywater systems operating under low energy and low maintenance requirements are typically preferred (Nolde, 2005); they are more cost effective, hence plays a key role in the uptake of greywater reuse schemes. Wetland systems, a natural based treatment technology, constitute an example of such a technology. It, however, may not be applicable in tight urban areas because of high space demand (Li et al., 2009). Biofiltration systems, on the other hand,

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operate under similar principles as wetland systems but require a much smaller footprint (Bratieres et al., 2008; Payne et al., 2015). Biofiltration systems, thus, potentially represent a more suitable low cost, low maintenance on-site greywater treatment approach for use in tight urban areas.

Living walls, which refer to “vegetation that grows directly onto a building façade or to vegetation that is grown on a separate structural system that can be freestanding or adjacent or attached to the wall” (Loh, 2008; Fig. 1 (left)), is an emerging green urban technology. It has a small footprint and can markedly help increase the sustainability and liveability of urban cities (Pérez-Urrestarazu et al., 2015; Loh, 2008) through its multiple benefits, including microclimate, aesthetics and amenity benefits, increase in urban biodiversity and reduction in the adjacent building energy consumption. However, one of the barriers impeding its widespread implementation is the high energy requirements to irrigate and maintain the living wall system (Pérez-Urrestarazu et al., 2015). While some systems are currently being watered with recycled greywater (Hopkins and Goodwin, 2011), there is currently no performance data regarding the use of these systems for greywater treatment although much potential to do so exists.

It is proposed to develop an effective and reliable system that can simultaneously maintain the living wall and treat greywater on-site for outdoor re-use applications - a conceptual diagram of the technology is shown in Fig. 1 (right). It is proposed to use a sand based media (or filters) placed near a building to support vegetation that grows up and along-side the building's façade. The proposed system will function as a biofiltration system and will provide treatment through physical (straining, sedimentation), chemical (adsorption, precipitation) and biological (plant and microbial assimilation, other microbial processes) processes as water percolates vertically down through the filter media. It will differ in its operation and design from wastewater wetlands and stormwater biofilters in a number of aspects. For instance, the proposed greywater living walls will be less saturated (it is speculated that the upper filter layers will experience more aerobic conditions) than vertical wastewater wetlands as it is very likely that systems will not receive any inflow for a large portion of the day while households are at work. Stormwater biofilters, on the other hand, operate under lower influent pollutant loads and more ephemeral conditions, with long dry periods between inflow events. Given that operating conditions such as loading rate, rest period between water application and influent pollutant concentrations have all been found to affect treatment efficiency (e.g. Akratos and Tsihrintzis, 2007; Kadlec and Knight, 1996; Vymazal, 2005), it is critical to develop these systems specifically for the proposed application. Another aspect in which the proposed system distinguishes from the former two systems relates to the type of vegetation employed to effectuate treatment. Plants in greywater living walls will mainly include climbing plants (comprising both deciduous and evergreen species), and lower storey ornamentals. Given that plants play an important role in pollutant removal and that plants present species-specific pollutant removal efficiency (Fraser et al., 2004; Bratieres et al., 2008), it is imperative to study the treatment ability of living wall plants. Currently there is no clear understanding how climbing plants and ornamentals affect nutrient removal from wastewater or stormwater.

It has previously been found that the presence of a saturated zone at the bottom of stormwater biofilters can help plant survive during dry periods, as well as improve pollutant processing (particularly nitrogen removal) (Zinger et al., 2007; Payne et al., 2014). Therefore the design should investigate inclusion of a saturated zone. The long-term performance of such a system will also reliant on a sustained hydraulic performance (Le Coustumer et al., 2012; Langergraber et al., 2003).

To our knowledge this is the first study in literature that aims to investigate a range of ornamental flowers and climbers as living walls (compared to conventional biofilters with freestanding plants) for greywater treatment. A large-scale, laboratory-based column study was conducted over a one-year period and

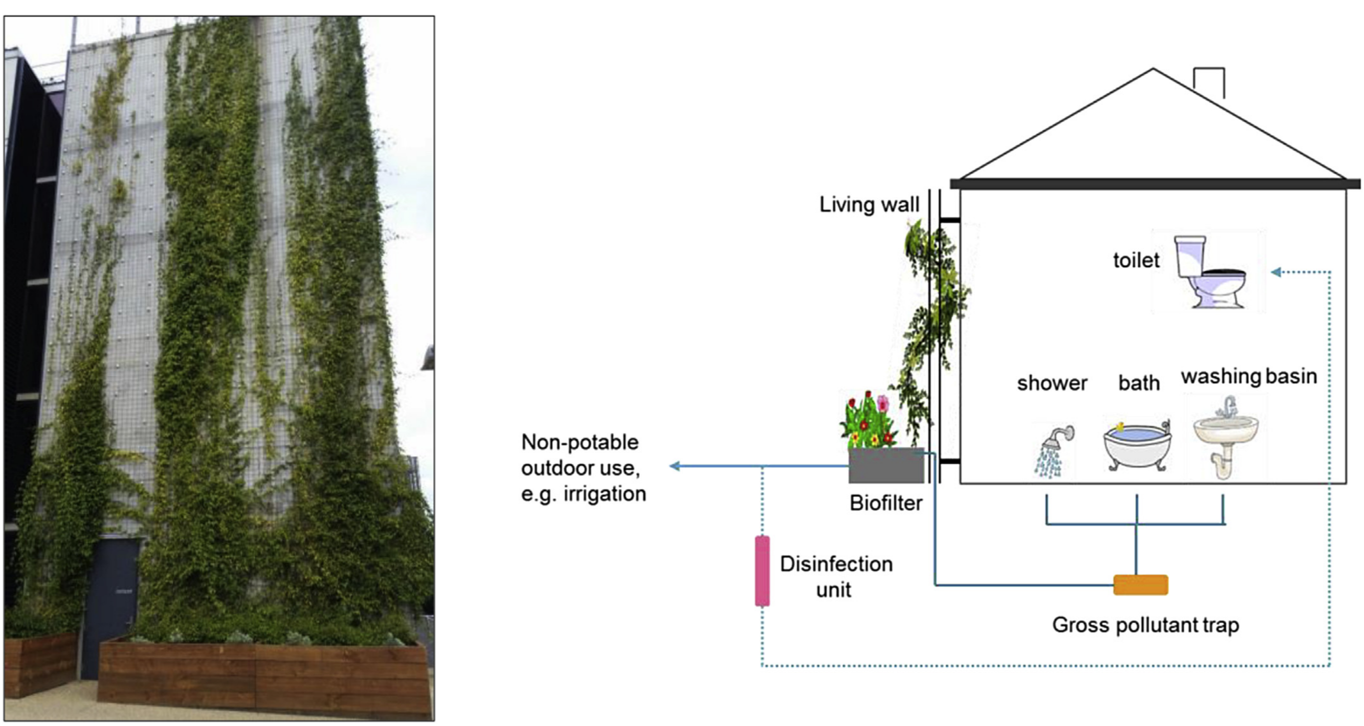

Fig. 1. A living wall used as part of urban landscaping at Monash university campus (left); concept of living walls for greywater treatment (right).