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Greening walls for treatment and reuse of domestic greywater

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Abstract

In this study, we describe a sustainable system for treatment and reuse of grey wastewater in urban areas through vertical green walls constructed on unused surfaces of buildings. The system integrates the benefits linked to the introduction of green spaces in urban areas with the advantages connected with the reuse of purified greywater (non-potable reuse) and the reduction of potable water use, allowing a sustainable use of water resources. We constructed a vertical green wall composed of modular panels with 12 vegetated pots per panel. The green wall was irrigated with synthetic greywater, and the removal efficiency was monitored weekly with regards to different parameters (e.g., BOD_5, COD, nitrogen, phosphorus). The results showed good results in terms of treatment performances, indicating the suitability of the green wall for treatment of greywater.

Keywords: domestic wastewater, green walls, greywater treatment, nature-based solutions, sustainable water management

1. Introduction

The sustainable management of water resources is one of the most concerning challenge to cope with water scarcity and increasing water demand (Friedler & Hadari, 2006). The treatment and the reuse of wastewater (WW) represent a valid and convenient solution that is progressively spreading, turning WW from a waste to a valuable resource for water, energy, and nutrients. Specifically, the portion of wastewater more suited for treatment and reuse is greywater (GW). GW is defined as household wastewater made of all domestic WW with the exception of toilet flushes (i.e., WW produced in bathtubs, showers, hand basins, laundry machines and kitchen sinks) (Eriksson, et al., 2002). GW may represent up to 75% of total domestic WW volume, accounting for up to 100-150 L/PE/day in high-income countries, and for smaller volumes in low-income countries (Ghaitidak & Yadav, 2013). The separation of domestic WW into grey and black water can reduce the daily volume of urban WW and to minimize the energy required for its treatment (Remy, 2008; Larsen, et al., 2009). Additionally, reclaimed GW could be recycled for other uses (e.g., toilet washing, irrigation), which would otherwise employ high-quality water; in this way, a circular economy is promoted (Masi, et al., 2018). Recently, a large body of research has been focused on the reuse of greywater treated by nature-based technologies, that allow to couple environmental, economic and energetic benefits. However, it is still necessary to better understand and evaluate the ability of these green systems to efficiently remove the contaminants.

2. Pilot System

2.1. Synthetic greywater

The experimental tests were performed using synthetic GW. We used a light GW obtained following the recipe proposed by Diaper et al. (2008), commonly used in literature (Prodanovic et al., 2017). Synthetic GW parameters are comparable to those of real GW (Hourlier et al., 2010).

Table 1. Physico-chemical characteristics of greywater input

Parameter	Raw greywater
pH	7.0 – 7.7
T (°C)	3.5 – 15.3
EC (µS/cm)	430.0 - 582.0
DO (mg/L)	6.9 – 13.1
BOD (mg/L)	0.5 - 54
COD (mg/L)	66.0 – 381.0
TDS (mg/L)	417.0 – 467.0
TSS (mg/L)	6.0 - 15.4
SO_4 (mg/L)	58.0 – 100.0
Cl^- (mg/L)	< 0.2 – 12.0
TN (mg/L)	0.5 – 11.2
NO_3^- (mg/L)	1.9 – 5.7
NH_4^+ (mg/L)	0.1 – 3.3
TP (mg/L)	0.7 - 16.0
MBAS (mg/L)	2900.0 – 4050.0
E. Coli (CFU/100mL)	> 1600.0 – 250000.0

2.1. Laboratory setup

We tested different mixes of coconut fibers and perlite and we chose a mix composed by 80% of coconut and 20% of perlite on the basis of a compromise between hydraulic conductivity and specific weight. Our system is composed by panels attached to the wall surface (Figure 1). Each panel contains a total of 12 vegetated pots, arranged in a pattern of 3 rows and 4 columns. The plant species varies among rows, with *carex morrowii* on the top row, *hedera helix* on the middle row and *lonicera nitida* on the lowest row. We considered three replicates, i.e. three columns with the same experimental setup in order to quantify the statistical variability in contaminant removal efficiency. Two configurations with the same growing material were tested, the first one being irrigated with tap water and the other one with GW. The first configuration was designed as a control setup to test the possible release of solutes and fine particles from the growing medium, while the second configuration was used to evaluate the removal efficiency of the system.

Figure 1. Pilot system installed in the courtyard of the laboratory.

The green wall was irrigated in a batch mode, with a hourly flush with a duration of 15 minutes. Each panel had a vertical surface of about 1 m^2 and received 100 L/day, that is the average daily production of GW per capita in high-income countries. GW was pumped from a 500 L tank to the panels through a pressurized pipe system. Each 15-minutes irrigation flush fed 1 L of GW to each pot in the top row. The feeding was regulated by drippers that guarantee a constant discharge. Water pumped to the top row of pots then leached through the lower pots of the same column, and it was eventually collected in a small tank placed below the panels, from which it was disposed of. Each pot has a horizontal surface area of 0.032 m^2, resulting in a value of hydraulic loading rate about 750 $L/m^2/day$.

Water samples were collected weekly from outflow pipes at the bottom of the lowest pots. A number of water quality parameters were monitored including BOD_5, COD, nitrogen, phosphorus, E. Coli, sulfate, MBAS (i.e. anionic surfactants), and dissolved oxygen.

3. Results

Results for the removal of BOD_5 are shown in Figure 2. The figure shows the inflow and outflow concentrations over time for the two configurations (with tap water and with greywater). The removal performance of the system was monitored over a period of more than three months. For the control panel irrigated with tap water, outflow concentrations were almost always higher than the inflow concentration. This behavior can be explained considering the organic nature of the coconut coir that causes an enrichment in BOD_5 of the tap water. The results hence indicate a release of organic matter residuals from the growing medium. Conversely, BOD_5 was almost completely removed by the configuration irrigated with GW, which exhibited removal efficiencies close to 100% and very low concentrations in the effluent.

The system performed well also for the other contaminants, with removal efficiencies that were low at the start of the experiment but progressively increased over time until reaching higher values. Observed ranges of efficiency were 4% to 82% for COD, -12% to +52% for TN, -22% to 57% for TP, and 95-100% for E. coli.

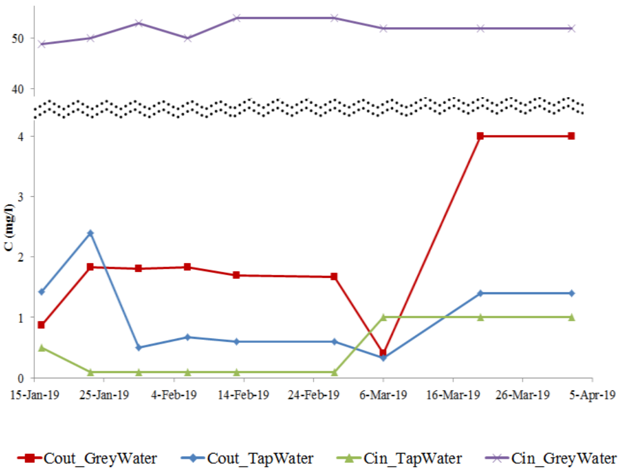

Figure 2. Biological Oxygen Demand (BOD_5): inflow and outflow concentrations over time during the monitoring period.

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