Treatment and reuse of greywater in different settings of green walls

Istenič, D.*,***, Trošt Sedej, T.**, Griessler Bulc, T.*,***, Radinja, M.*** and Atanasova, N.***

*Faculty of Health Sciences, University of Ljubljana, Zdravstvena pot 5, 1000 Ljubljana, Slovenia; darja.istenic@zf.uni-lj.si, tjasa.bulc@zf.uni-lj.si
**Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia; tadeja.trostsedej@bf.uni-lj.si
***Faculty of Civil and Geodetic Engineering, University of Ljubljana, Jamova cesta 2, 1000 Ljubljana, Slovenia; matej.radinja@fgg.uni-lj.si; natasa.atanasova@fgg.uni-lj.si

Highlights:

- Green walls can be designed with an aim to treat greywater (intensive green walls)
- Intensive green walls enable efficient treatment of greywater for non-potable reuse
- Ornamental green walls can be fertigated with greywater to avoid the use of potable water and mineral fertilizers

Keywords: treatment wetland; perlite; rock mineral wool

INTRODUCTION

The climate crisis, phosphorous and water scarcity due to linear utilisation require the development and implementation of innovative concepts for resource management. Wastewater can be reused as an "end-of-pipe" solution in centralised systems or as an on-site solution in decentralised systems, which can reduce investment in infrastructure, enable better control of the wastewater source and thus increase the feasibility of water and nutrient reuse. Greywater, defined as water from showers, sinks, laundries and kitchens, is a reliable and stable water source that can replace rainwater or potable water for certain purposes (e.g. toilet flushing, irrigation). The design and use of green walls for greywater treatment is receiving increasing attention in the scientific community, with a focus on hydraulic design, media, co-benefits, etc. (e.g. Masi et al. 2016; Galvão et al., 2022; Pucher et al., 2022). Green walls for greywater treatment thus represent an upgrade of the ornamental green walls with the functions of treatment and resource recovery. They function as vertically arranged treatment wetlands that produce treated water for further use.

On the other hand, the introduction of ornamental green walls is spreading due to their positive impact on the urban environment both indoors and outdoors (reduction of the heat island, noise mitigation, air purification, biodiversity) and their aesthetics. They differ from green walls for greywater treatment by their geometry and structure, i.e. they are thinner, have less and different media and are not designed for water treatment. Conventional ornamental green walls are irrigated with potable water and fertilised with mineral nutrients, which increases their environmental impact. The water and nutrients are supplied according to the needs of the plants, resulting in minimal outflow. The use of greywater for the irrigation of green walls would contribute to the reuse of resources and savings on potable water and mineral fertilisers.

This paper evaluates the performance of a conventional ornamental green wall fed with greywater in terms of plant health and potential treatment performance. The results are compared with the performance of a green wall designed for greywater treatment. In addition, the reduction in environmental impact compared to a conventional ornamental green wall irrigated with potable water is estimated.

METHODOLOGY

An experimental indoor ornamental green wall was set up on the premises of the Faculty of Civil and Geodetic Engineering, University of Ljubljana. It is a conventional modular green wall manufactured by Urbanscape®, Knauf Insulation Ltd. from Slovenia (Figure 1). The experimental ornamental green wall consists of nine 62 x 52 cm modular panels combined in a 3 x 3 modular green wall. The modular panels are made of mineral rock wool, which has a high water retention capacity (Istenič et al., 2024). The first column (A) serves as a control and is irrigated with potable water with the addition of mineral fertiliser, the second (B) and third (C) columns are fed with synthetic greywater according to Pucher et al. (2022). The plants in columns A and B are potted in a peat-based planting substrate, as is common with Urbanscape® green walls, while the plants in column C are potted in shredded rock mineral wool to prevent additional nutrients from entering the system with the planting substrate. The pilot system was set up in summer 2024 and is monitored for water consumption, COD, BOD, NH_4-N, NO_3-N and PO_4-P, T, pH, EC and dissolved oxygen. Plant stress is also monitored using photochemical efficiency and pigment measurements.

Figure 1: Scheme of Urbanscape® ornamental green wall tested irrigated with greywater (Source: Knauf Insulation Ltd.).

At the same time, we test the performance of the green wall for treating greywater, which is installed next to the ornamental green wall. The green wall for greywater treatment consists of 4 cascading stainless steel beds (160 x 20 x 26 cm), arranged at a vertical distance of 25 cm between each bed. Each bed is lined with felt and filled with a mixture of perlite (2-6 mm), sand (2-6 mm) and coconut fibres in a ratio of 1:1:0.02. The green wall is fed with the same greywater as the adjacent green ornamental wall at a flow rate of 133 L/d into the upper bed, from where it flows through each bed with a horizontal subsurface flow. The flow rate is based on previous experiments on the green wall. The beds are equipped with air blowers to allow aerobic conditions. The green wall is monitored simultaneously with the ornamental green wall for the same chemical and physical parameters over the following months. The results of both systems will be presented at the conference.

RESULTS AND CONCLUSIONS

Greywater as an alternative water source will be tested on a conventional ornamental green wall and the effluent will be compared to a discharge from a green wall designed for greywater treatment. We expect that the effluent concentrations will be similar for the green wall treating greywater and in column C of the ornamental green wall due to the absence of sources of organic matter and nutrients. Next, we expect that greywater will provide sufficient nutrient concentrations to support the growth of plants in the conventional green wall. The responses of plants to greywater may be species-specific, so it is necessary to monitor stress responses in different species. Preliminary measurements of plant stress have shown that plants in ornamental green wall irrigated with greywater did not show significant stress in terms of photochemical efficiency; however, there were differences in plant photosynthetic and protective pigments. In the long term, we expect better plant health in column A being irrigated with potable water with the addition of mineral fertilizers compared to columns B and C which receive greywater due to potential overload and toxic effects of pollutants in greywater.

The treatment performance of the green wall in the previous experiments reached a removal of up to 70% for COD, 74% for BOD, 20% NH_4-N, and 72% NO_3-N, with an organic loading rate of 33 g COD/m^2d and 7 g BOD/m^2d. Average outflow concentrations were 88, 15, 3, and 1 mg/L for COD, BOD, NH_4-N, and NO_3-N, respectively.

The setting of the two experimental walls also enables the possibility of treating greywater in a green wall and using the treated effluent to irrigate the ornamental green wall.

ACKNOWLEDGEMENTS

The study was performed with the financial support of the Slovenian Research Agency, namely Program Group P3-0388 and Project L7-4495.

REFERENCES

Galvão, A., Martins, D., Rodrigues, A., Manso, M., Ferreira, J., Matos Silva, C. 2022. Green walls with recycled filling media to treat greywater, Science of The Total Environment, 842: 156748. https://doi.org/10.1016/j.scitotenv.2022.156748.

Istenič, D., Prosenc, F., Zupanc, N., Turel, M., Holobar, A., Milačič, R., Marković, S., Mihelič, R. 2024. Composting of recovered rock wool from hydroponics for the production of soil amendment, Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-024-33041-2

Masi, F., Bresciani, R., Rizzo, A., Patwardhan, N., Panse, D., Langergraber, G. 2016. Green walls for greywater treatment and recycling in dense urban areas: a case-study in Pune. Water, Sanitation & Hygene for Development, 6: 342-347. https://doi.org/10.2166/washdev.2016.019

Pucher, B., Zluwa, I., Spörl, P., Pitha, U., Langergraber, G. 2022. Evaluation of the multifunctionality of a vertical greening system using different irrigation strategies on cooling, plant development and greywater use, Science of The Total Environment, 849: 157842. https://doi.org/10.1016/j.scitotenv.2022.157842.