Greywater purification in prefabricated façade elements derived from construction and demolition waste

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Introduction

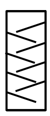
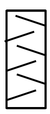
On-site greywater treatment and reuse constitute worthwhile contributions to regional water distribution and scarcity challenges. Water consumption in a European household is around 140 l per person/day, half of it is greywater, i.e. deriving from non-fecal sources such as sinks, showers, baths, washing machines. To make a major contribution to water savings through building integrated technologies, a prefabricated building block is developed that integrates a grey and storm water management unit on a constructed wetland basis. This modular panel consists of over 70 % of construction and demolition waste (CDW) addressing also the great challenge of rapidly growing CDW shares in the EU. Main application areas of the technology are objects in regions with water distribution or scarcity challenges and those associated with high water consumption rates, such as accommodation facilities in arid areas. While the interior layer of the panel is associated with functions of building energy-efficiency and acoustic performance, the exterior panel holds the living green wall with the associated water treatment unit.

The collected grey and storm water is inserted in the panel top and flows along a purpose-built water path with maximised water retention time to the panel bottom. On its way in penetrates plant roots and reacts with the microbiome of the ecosystem, where in a process of degradation, the water is purified. Several vertically arranged panels allow for a continuous flow to achieve optimum purification rates at the end of the undermost panel. To test this technology 3 types of encasings, with various flow control systems and substrate mixes were tested.

Material & methods

To test the purification performance of the façade-integrated constructed wetland. 3 types of encasing models, made of wood and acryl glass were tested outdoors with southern orientation in Vienna, summer 2017. Each model followed a distinct flow path and was planted with a mix of marsh plants in an expanded-clay substrate. Chan1 and Chan2 differ in terms of substrate filling, leading to 4 model types (table 1). The plants were inserted through holes of 3 cm diameter on the model front. Inflow velocity of the artificial greywater was approx. 200 ml/min. Measurements were conducted using a spectrophotometer for the parameters COD, BOD_5, TSS, TOC, DOC and turbidity. Ammonium $N\text{-}NH_4^+$, nitrate $N\text{-}NO_3^-$ and phosphate PO_4^{3-} were measured photometrically.

Table 1. properties of test models

Model	Flow path design	Sketch	Substrate	Dimension	Plants
No.1A **Chan1**	Vertical tube		100% expanded clay	100 cm high elliptic cross section (31 cm^2)	5
No.1B **Chan2**	Vertical tube		75% expanded clay 25% coconut fibres	100 cm high elliptic cross section (31 cm^2)	5
No.2 **Pan_Decline**	8 Cascades with 1° declining slope		100% expanded clay	80 height x 40 width x 5 depth [cm]	24
No.3 **Pan_Incline**	6 Cascades with 5° inclining slope (effecting retention basins)		100% expanded clay	100 height x 50 width x 5 depth [cm]	18
Control	Vertical tube		100% expanded clay	100 cm high elliptic cross section (31 cm^2)	-

Results & discussion

In tables 2-5 an illustrative excerpt of all measured parameters is presented, containing inflow values and effluent values of all 4 models as well as a control model for biochemical oxygen demand, chemical oxygen demand, total organic carbon and ammonium.

Table 2. comparison biochemical oxygen demand

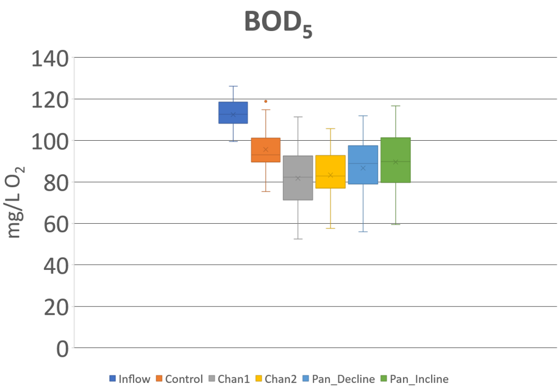


Table 3. comparison ammonium removal

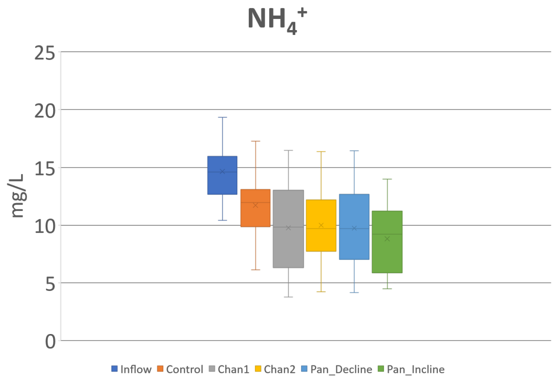


Table 4. comparison chemical oxygen demand

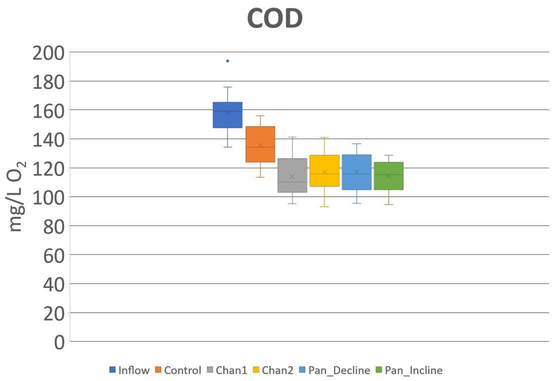
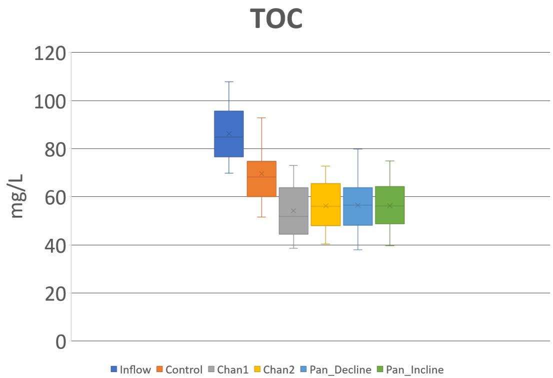


Table 5. comparison total organic carbon removal



A significant statistical difference in purification potential comparing the four models with the control channel was observed (α 5%). Surprisingly, no significant difference was observed comparing the removal potential of the four models among each other regarding all parameters. Chan1 and Chan2 performed equally well as both cascading models, though water retention time was significantly higher in the latter. The reason for this could be traced to: 1. the vertical stress experienced by the plants inside the cascading models as they did not have a support structure at the planting holes. This likely led to reduced root growth and thus impeded performance.

Further analyses with improved models are planned. To achieve better treatment performance, it is planned to manufacture a CDW-based aluminium encasing effecting in improved sealing to increase retention time. All encasings will incorporate plant support against gravity stress, likely to significantly raise purification rates. Textile fibres mixed to the substrate will be tested for their impact on substrate cohesion and associated root growth. Eventually, the simulations with the current design settings suggest, that an optimized 5-6 m high living green wall should be able to achieve the aspired water quality reuse standards. Potential objects to be equipped with the prefabricated green panels range from tourist industry, manufacturing industry, publics buildings to small residential buildings.

Table 5. Simulation of 5m Chan1and effluent requirements

Parameter	Effluent Chan1	Effluent goal	Legislation[1,2]
BOD5 (mg/L)	60	< 15	10-70, 25
COD (mg/L)	90	< 40	60-100, 125
TSS (mg/L)	18	< 10	5-35, 35
Turbidity (NTU)	16	< 2	1-15, 2-10

References

1 Alcalde-Sanz, L. & Gawlik, B. M. (2014) Water reuse in Europe: relevant guidelines, needs for and barriers to innovation: a synoptic overview. Luxembourg: EUR-OP.
2 European Commission (1991) Directive 91/271/EEC on Urban Waste Water Treatment.

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