Innovative water treatment with the Vertical Ecosystem for an optimal and safe closed water cycle in tourist facilities

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Abstract
The Vertical Ecosystem is a greywater purification system based on indoor constructed wetlands with cascading set-up that combines sub-surface horizontal water flow with stage wise vertical flow. Two test units with three and four levels of plant containers installed at the laboratory of alchemia-nova and at a hotel in Spain have been tested under simulation and real conditions for tourist facilities. The investigated plant species function in symbiosis with rhizosphere microorganisms providing water-cleaning abilities. Special focus lies on practical considerations regarding bottlenecks for market uptake of this concept. In relation to EU-legislations and recommendations the effluent of the Vertical Ecosystem can be used for toilet flushing, irrigation of private gardens, golf grounds, groundwater recharge and laundry, at the studied level of greywater pollution load and flow throughput.

Keywords
Vertical Ecosystem, water management, indoor water purification, constructed wetland

INTRODUCTION

In Mediterranean countries water resources are limited and unequally distributed in space and time. For this reason, public administration tries to improve water management, water pricing and water recycling policies to enhance and ensure water supply and achieve a sustainable water management (demEAUmed, 2015). Reduction of freshwaters consumption in hotel facilities, green and recreational areas, etc. is achieved by using alternative water sources, such as ground water, treated rainwater or the reuse of treated greywater and/or wastewater. This Vertical Ecosystem (VertECO) will solve the problem of reducing the consumption of drinking water by providing a technological solution based on plants (Zraunig et al., 2015). It will be tied into the greywater treatment cycles of the building and will support significant potable water savings by reusing water flows on site, e.g. for flushing toilets.

MATERIAL AND METHODS

The laboratory scale plant-based greywater treatment unit imitates real life conditions of a demonstration site located in a hotel at the Costa Brava in Spain. This unit is monitored for cleaning performance, microbiological factors, chemical pollutants, reliability, maintenance and energy demands. For the constructed plant based wetland a vertical stage wise set-up has been used combined with a sub-surface horizontal water flow (Vaymazal, 2011). The laboratory small-scale wetland consists of three floors, connected by water tubes. A pump, with time controlled operation, feeds (grey)water from a buffer tank into the top floor. Water flows in a sub-surface horizontal manner, meandering through the rhizosphere and pushed down to the next floors by gravity. In order to improve the aerobic symbiosis (Stottmeister et al., 2003) of roots and microorganisms, air is continuously injected through perforated hoses at the bottom of the plant containers into the water. More than 90 plants (marsh plants, graminoids, tropical and subtropical plants) in different combinations were tested. The effluent from the Vertical Ecosystem was for water quality defining parameters analysed and compared to the initial values from the synthetic greywater to allow a performance appraisal. The slightly bigger unit at the hotel in Spain is constructed and has been tested in the same way.

RESULTS AND DISCUSSION

Table 1 compares values of key water quality parameters (reference values for pollution loads) for the synthetic greywater mixed at the laboratory in Vienna for test purposes and the values for the

final outflow from the Vertical Ecosystem unit after the water has been treated. These values are averaged and condensed from a period of 12 months of tests with the unit at different greywater loads. Pollution abatement and water cleaning performance is considerable.

Table 1. Synthetic greywater (inflow), effluent water after treatment

Parameter	Unit	Simulated Greywater	Effluent
COD	mg O_2/L	336	8,9
BOD_5	mg O_2/L	238	3
TSS	mg/L	46,9	4,61
Conductivity	µS/cm	431,4	423,1
Nitrate	mg/L	0,8	0,1
Turbidity	NTU	43,9	0,3

COD (chemical oxygen demand) and BOD_5 (biological oxygen demand) are very important in order to assess the cleaning performance of the system. Our sampling points are the greywater tanks with the synthetic mixture, after 175 L rhizosphere (1st floor), after 350 L rhizosphere (2nd floor) and after 525 L rhizosphere (3rd floor). Drastic reductions in the COD and BOD_5 parameters are obtained after the first cleaning stage, then this decrease levels off in an approximately logarithmic manner and at values of about 8,9 mg O_2/L for COD and 3 mg O_2/L for BOD_5. Further decreases do not seem practical anymore for a reasonable size (=root area) of the unit similar conclusions can be drawn for TSS (total suspended solids).

CONCLUSIONS

Based on Table 1. a considerable cleaning performance of water was achieved by the Vertical Ecosystem. In relation to Spanish/EU legislations, preliminary results seem to indicate that the effluent of the Vertical Ecosystem can be used for applications with lower water quality requirements like toilet flushing, irrigation of private garden, golf irrigation, groundwater recharge and laundry, at the given load of greywater pollution and flow rate input of approx. 1 L greywater per L of root volume per day. Microbiological tests for key indicator species are still pending, but the target water streams at the (Table 2.) demonstrations site at the hotel did not show any problems with microbiological load, probably because those water streams get chlorinated quite intensely.

Table 2. Pertinent regulatory guidelines for water quality for on-site recycled water compared to the results from the Vertical Ecosystem unit

			Potential Re-uses of VertECO effluent					
				Groundwater recharge		Irrigation		
	Simulated greywater effluent	Water effluent after VertECO	Laundry	Direct injection	Localized ground percolation	Private garden irrigation	Golf irrigation	Toilet flushing
European Directive			91/271/EC	91/271/EC	91/271/EC	91/271/EC	91/271/EC	91/271/EC
Spanish Legislations				RD 1620/2007	RD 1620/2007	RD 1620/2007	RD 1620/2007	RD 1620/2007
COD (mg/L)	336	8,9	125			125	125	
BOD_5 (mg/L)	238	3	25			25	25	
TSS (mg/L)	46,9	5	< 60	10	35	10	20	10
Conductivity (µS/cm)	287,83	423				6000	6000	
Nitrate (mg/L)	0,8	0,1		25	25			
Turbidity NTU	43,9	0,3		2		2	10	2

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