Combination of various solid wastes with fragmented limestone as filler for constructed wetlands used for wastewater treatment

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Abstract

This study aims to contribute to the development of eco-efficient constructed wetlands (CW) through the concept of circular economy and the use of waste to treat waste. Combinations of five solid wastes were evaluated as filler materials for CWs used for wastewater treatment. To evaluate the combined capability of the waste materials to wastewater treatment, five sets of unplanted lab-scale CWs were established. The CWs were operated in a discontinuous mode for three successive fill-and-drain cycles. The highest COD removal rate was obtained for a CW filled with limestone and cork waste (90.3±0.9%). The highest total nitrogen removal rate were obtained for a CW filled with limestone and clay brick fragments (84.8±0.1%). Total phosphorus removal percentage of 91.8±0.1 was achieved for a control CW filled with limestone. It was observed that layer-packed solid waste combination fillings are adequate in improving COD removal in limestone based CWs, and that all but the limestone-snail shells filling have a very good performance for total nitrogen and total phosphorus removal from wastewater.

Introduction

Constructed wetlands (CWs) are a green technology for wastewater remediation, engineered to simulate natural wetlands with an improved control over the treatment capabilities. CWs have efficiently been used to treat diverse types of wastewater in the last few decades, but are still the object of intense research. Despite representing a lower-energy and less-operational requirements alternative to the conventional wastewater treatment systems, CWs are land-intensive and it is consensual that their sustainability still remains a challenge. This study aims to contribute to the development of an eco-efficient design through the concept of circular economy and the use of waste to treat waste.

Material and Methods

Combinations of five solid wastes were evaluated as filler materials for CWs used for wastewater treatment:

- cork granulates resulting from the cork industry;
- snail shells resulting from the food and catering industry;
- coal slag resulting from power plants;
- clay brick fragments; and
- limestone rock fragments, both resulting from construction activities.

To evaluate the combined capability of the waste materials to wastewater treatment, five sets of unplanted lab-scale CWs were established. They were located indoors and consisted of truncated cone pots in opaque plastic with 35.0 cm x 31.5 cm x 39.0 cm in height, lower and upper diameter. A reference set was filled only with limestone fragments, already shown to be a good CW substrate. The remaining four sets were filled with three layers, a 7 cm bottom layer, a 7 cm top layer of limestone fragments and a 15 cm inner layer of each of the evaluated waste material. This combination of materials was intended to increase the CWs' removal of organic and nitrogen compounds from the wastewater, limestone had particularly been shown to remove phosphorous compounds. The water level was maintained 3 cm below the surface of the top layer to avoid contact with the atmosphere, as usual in subsurface CWs.
Analysis of COD, total nitrogen and total phosphorous were made with Hanna Inst. wastewater analysis kits, heat block HI839800 and photometer HI83399.

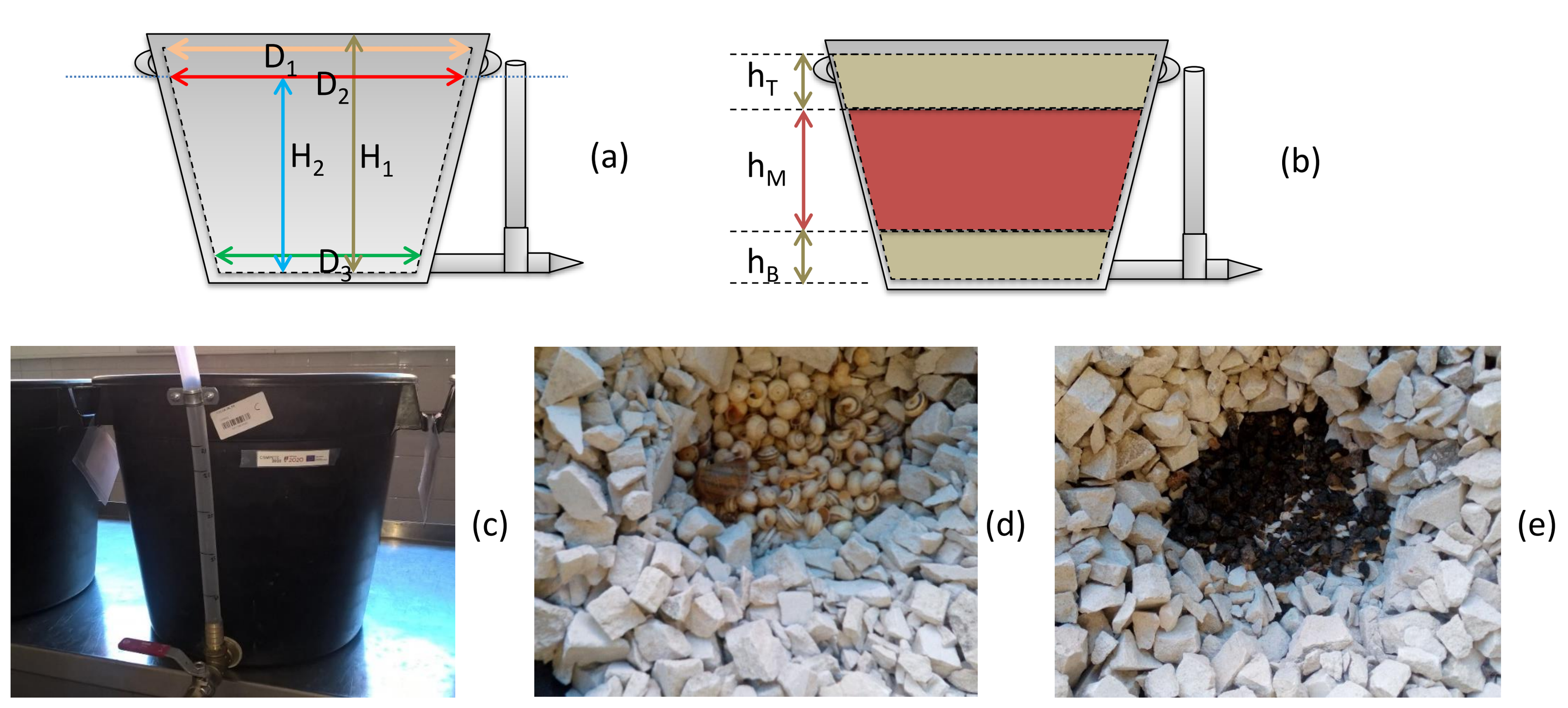

Figure 1 – Lab CWs schemes and pictures: (a) pot dimensions (m); H_1 = 0.350; H_2 = 0.295; D_1 = 0.390; D_2 = 0.385; D_3 = 0.315; (b) waste solids filling heights (m); h_B = h_T = 0.070; h_M = 0.150; (c) photo of a pot; (d) photo of one mixed-filler of snail shell and limestone; (e) photo of one mixed-filler of cork and limestone.

Results

Table 1 presents the hydraulic loading rate (HLR) and the bulk porosity for each CW type. The hydraulic retention time was 6 days. Figure 1 shows the experimental removal rates of COD, TN and TP from the wastewater. COD removal percentages of 90.3±0.9, 83.8±1.0, 83.0±0.3, 77.2±1.3 and 68.0±1.3 were achieved for the LCS, LCG, LSS, LBF and LO CWs, respectively. The highest removal rate was obtained for the LCS CW and the lowest for the control LO CW, indicating that all the waste materials are good CW fillers for the removal of oxidable compounds. It is not surprising that the LCS CW had the best removal rate, once its HLR was almost half of that of the other CWs. Removal percentages for total nitrogen were 84.8±0.1, 82.2±0.3, 75.1±0.1, 55.4.0±0.3 and 43.6±2.0 for the LBF, LCS, LCG, LO and LSS CWs, respectively. The highest removal rates were obtained for the LBF CW and the lowest for the LSS CW. Total phosphorus removal percentages of 91.8±0.1, 86.6±0.3, 76.5±2.5, 76.5±0.1 and 11.8±1.9 were achieved for the LO, LCS, LBF, LCG and LSS CWs, respectively. The LO CW had the highest removal rates, as expected.

Table 1 – Lab CW solid waste layer structure, hydraulic loading rate and bulk porosity.

Bottom layer	Midlle layer	Top layer	CW	HLR (m/day)	Porosity
Limestone	Limestone	Limestone	LO	0.014 ± 0.003	0.388 ± 0.007
Limestone	Cork granulates	Limestone	LCG	0.015 ± 0.001	0.404 ± 0.006
Limestone	Snail shells	Limestone	LSS	0.016 ± 0.001	0.442 ± 0.017
Limestone	Brick fragments	Limestone	LBF	0.014 ± 0.001	0.371 ± 0.013
Limestone	Coal slags	Limestone	LCS	0.007 ± 0.001	0.186 ± 0.008

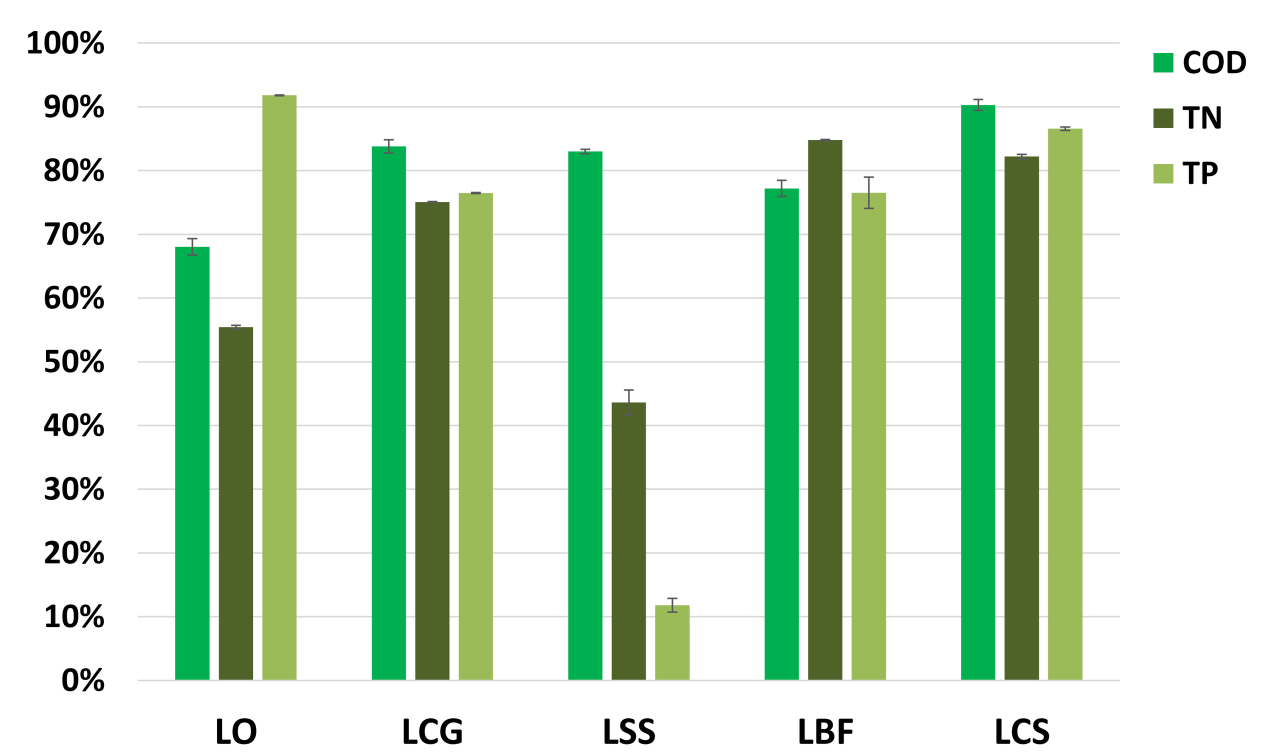

Figure 2 – COD, total nitrogen (TN) and total phosphorous (TP) removal rates.

Conclusions

It was shown that layer-packed solid waste combination fillings are adequate in improving COD removal in limestone based CWs, and that all but the limestone-snail shells filling have a very good performance for total nitrogen and total phosphorus removal from wastewater.
This innovative combination of different waste materials can be tuned to improve CW performance for different types of wastewater, while simultaneously contributing to the valorisation of solid waste.

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