Basic Oxygen Furnace steel slag and apatite for sustainable phosphorus removal at small wastewater treatment plants

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Abstract

Recent developments in phosphorus (P) removal have focused on P reactive materials to use within constructed wetlands (CW), as a sustainable alternative to chemical dosing. In this study, different fractions of Basic Oxygen Furnace (BOF) steel slag and apatite media have been tested in full-scale CWs, being the first trial of its kind in the United Kingdom evaluating the P removal capacity of both these media. Column experiments have also been carried out to confirm the effect of hydraulic retention time (HRT) on effluent pH. The results show that both materials can efficiently and consistently remove P. Smaller slag fractions are more efficient in P removal than larger fractions, but produce slightly higher effluent pH. Apatite shows a similar P removal as the smallest slag fraction, but produces lower effluent pH. The pH of all CW effluents is high at the start but decreases with time. HRT is a key operational parameter in controlling the effluent pH in this type of CW.

Keywords
Apatite; BOF steel slag; constructed wetlands; phosphorus

INTRODUCTION

Latest developments in phosphorus (P) removal have focused on the research of novel materials that can be employed as reactive media in constructed wetlands (CWs), as it is more sustainable than the traditional chemical dosing method for small wastewater treatment plants. This work focused on two of these materials, Basic Oxygen Furnace (BOF) steel slag and apatite. Both materials have been trialled at laboratory-scale with column experiments (Bellier *et al.*, 2006; Bowden *et al.*, 2009, Blanco *et al.*, 2016), and at pilot-scale CW (Barca *et al.*, 2014), but no full-scale CW results have been reported in literature yet. This work constitutes the first full-scale CW with these two media carried out in the UK, and will be used to identify optimum design and operational parameters for CW using these media for domestic wastewater treatment.

MATERIALS AND METHODS

The two materials have been tested in four CW in parallel with different media characteristics and operational parameters (Table 1), being fed by a proportion of the humus tank effluent, and preceded by percolating filters. A 24-hour composite has been taken once a week from the common inlet and each CW effluent. Column experiments with synthetic wastewater at different hydraulic retention times (HRT) have also been sampled for 45 days.

Table 1. Characteristics of the two materials employed and the four full-scale constructed wetlands (*SS: BOF steel slag, **APA: Apatite).

Bed n°	Material	Origin of supplier	Price	Product type	Particle size (mm)	Bed volume (m^3)	Inlet flow (m^3/d)	HRT (h)	Time in operation (d)
1	Large SS*				10 - 20	77.9	20	24	222
2	Medium SS	Wales	£	Waste product	4 - 10	77.9	20	24	217
3	Small SS				2 - 6	77.9	20	24	98
4	APA**	France	£££	Manufactured	2.5 - 8.5	77.9	20	12	234

RESULTS AND DISCUSSION

Slag results showed that on average, the highest effluent TP was produced by the largest slag fraction, which corresponded to an average of 0.54 mg/L (Figure 1). The smaller slag fractions achieved higher P removal rates, due to their higher surface area, which enabled higher CaO dissolution. Apatite results indicated that it achieved similar removal efficiency (97.7%) to the smallest slag fraction, but produced an effluent of a more consistent quality. This is thought to be due to the apatite having a considerably more homogeneous composition compared to slag. The apatite CW also showed slightly higher P removal capacity than any of the slag CW. The pH of the effluent was also dependant on the slag size, smaller fractions leading to higher effluent pH, linked to higher CaO dissolution. The pH of all effluents decreased with time, and the apatite CW showed the greatest decrease.

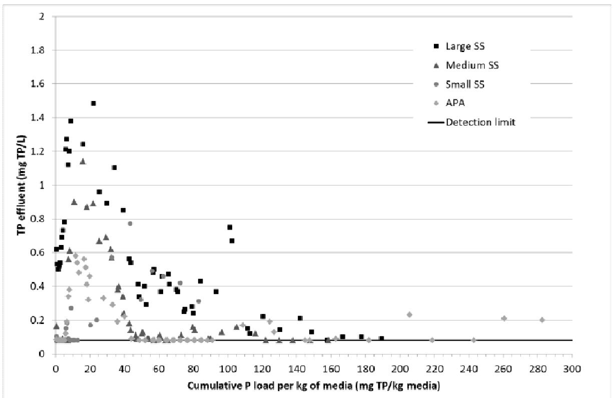

Figure 1. CW performance in relation to the cumulative total P load per kg of media in each CW.

The column experiments carried out at 6 h of HRT showed that the effluent pH dropped below 9 after 15 days of operation for both materials, while it remained above 10 for the whole duration of the experiment (Figure 2).

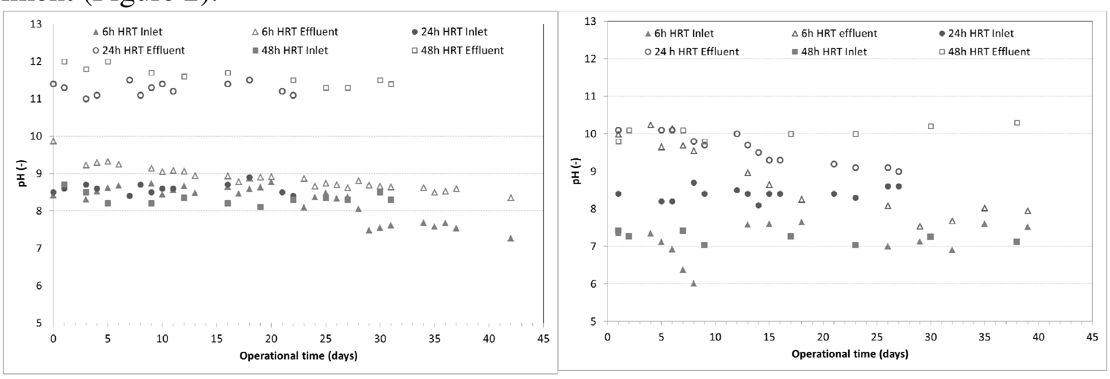

Figure 2. Slag column effluent pH at different HRTs (left) and apatite column effluent pH at different HRTs (right).

CONCLUSIONS

BOF steel slag and apatite have been proven to efficiently remove P from domestic wastewater in full-scale CWs. Compared to larger fractions, smaller steel slag fractions are more efficient in P removal, but produce slightly higher effluent pH. Apatite shows a similar P removal as the smallest slag fraction, but produces lower effluent pH. As expected, the pH of all CW effluents is high at the start of the trial but shows a decrease with time. HRT is a key operational parameter in controlling the effluent pH in this type of CW.

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