EFFECT OF *PHRAGMITES AUSTRALIS* GROWTH ON THE PERFORMANCE OF HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLANDS DURING THE START-UP PHASE

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ABSTRACT

Constructed wetlands (CW) are a suitable solution for wastewater treatment and normally require low maintenance, provide a natural appearance and present high pollutant removal efficiencies. During the start-up, the operating conditions and the characteristics of the influent may affect the adhesion and the development of both the biofilm and the plants that may affect the stability and performance of the beds. *Phragmites australis* is very sensitive to changes in operation conditions during the growth phase and its role on the performance of a horizontal subsurface flow constructed wetlands (HSSF-CW) during the star-up phase was investigated. Five experiments were carried out in two mesocoms (vegetated and unvegetated), for different organic and nitrogen loads, in order to evaluate the removal of COD, NH_4-N, NO_2-N and NO_3-N during the start-up (80 weeks of operation). The results showed that the development of *Phragmites australis* significantly affected the removal of organic matter during the first 11 weeks of operation, but there were observed steady-state conditions between weeks 11 and 16 and weeks 72 to 80. The removal of ammonia nitrogen was unstable during all the monitoring time, which would mean that mechanisms such as plant uptake and nitrification are more sensitive to changes in the operation conditions.

KEY WORDS

Phragmites australis, constructed wetland, start-up, organic removal, ammonia removal

INTRODUCTION

Horizontal subsurface flow constructed wetlands (HSSF-CW) are anoxic/anaerobic biofilm reactors. Direct atmospheric oxygen diffusion through the bed is low, but the release of oxygen through plants into the rhizosphere may benefit aerobic microbiological removal pathways (Kadlec *et al.*, 2000). The presence of fine roots and large aerenchyme in *Phragmites australis* may favour the transport of oxygen through the rhizosphere and, therefore, allowing a good development and adhesion of biofilm on roots and rhizomes (Vymazal and Kropfelova, 2008). However, the growth and development of *Phragmites australis* may be affected by the variation of the hydraulic loading rate or the characteristics of the influent that may affect the removal of organic matter, suspended solids and nitrogen as observed in Jing *et al.* (2002) and Albuquerque *et al.* (2009).

The removal of organic carbon and nitrogen is dependent on the characteristics of the influent, operating conditions and state of plant evolution, which also influences the steady-state conditions in the bed. Therefore, the evaluation of the role of *Phragmites australis* on the removal of organic carbon and nitrogen during the start-up of HSSF-CW may clarify its influence to enhance steady-state conditions in the bed.

The main objective of the work was to evaluate the effect of *Pragmites australis* on the removal of organic matter and nitrogen during the start-up of HSSF beds (over 80 weeks of operation), using vegetated and unvegetated mesocosms and different organic and nitrogen loads.

MATERIAL AND METHODS

Two HSSF-CW mesocosms (2x0.8x0.7m) were used in the experiments, filled with a lightweight expanded clay aggregate (Filtralite™) with a void ratio of 0.45 and a total effective area of 0.68 m^2. The water table was 0.2 m. One bed was planted with common reed (*Phragmites australis*) and the other was kept as a control unit (with no plants). Five experiments were executed (assays 1.1 and 1.2 for the unvegetated bed; assays 2.1, 2.2 and 2.3 for the vegetated bed), using a synthetic solution (based on sodium acetate and ammonia chloride). Assays 1.1, 2.1 and 2.3 run at the organic loading rate (OLR) of 10 g COD m^{-2} d^{-1} and the nitrogen loading rate (NLR) of 1 g NH_4-N m^{-2} d^{-1}. Assays 1.2 and 2.2 run at the OLR of 20 g COD m^{-2} d^{-1} and the NLR of 2 g NH_4-N m^{-2} d^{-1}. The flow-rate was kept constant at 1 L h^{-1} (which represented a hydraulic loading rate of 4 cm d^{-1} and a hydraulic retention time of 5 d). The beds were operated continuously and water samples were collected during the first 16 weeks (for assays 1.1 and 2.1) and between the weeks 64 and 80 (for assays 1.2, 2.2 and 2.3) at the influent and in three internal points (PI2, PI5 and PI8) of the beds for the determination of pH, DO, COD, NH_4-N, NO_2-N, NO_3-N, VSS and TSS

according to Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF, 1999).

RESULTS AND DISCUSSION

Table 1 presents the results for each series of experiments. The mass removal rates for COD (r_{COD}) and NH_4-N (r_{NH4}) were calculated based on the influent flow, the influent and effluent concentrations and the effective volume.

Tabel 1 – Results for each experiment

Parameters	Point	Assay 1.1	Assay 1.2	Assay 2.1	Assay 2.2	Assay 2.3
OLR (g COD m^{-2} d^{-1})	Influent	11.5 ± 0.3	19.5 ± 1.1	11.1 ± 1.4	17.7 ± 0.6	10.4 ± 0.3
r_{COD} (g COD m^{-2} d^{-1})	Inf-PI8	4.4 ± 0.3	8.6 ± 1.4	8.3 ± 1.9	15.5 ± 1.5	10.1 ± 0.3
NLR (g NH_4-N m^{-2} d^{-1})	Influent	1 ± 0.1	1.9 ± 0.2	1.4 ± 0.1	2 ± 0.1	1.1 ± 0.1
r_{NH4} (g NH_4-N m^{-2} d^{-1})	Inf-PI8	0.4 ± 0.1	0.6 ± 0.1	0.8 ± 0.2	0.8 ± 0.3	0.6 ± 0.1
Type of bed		Unvegetated	Unvegetated	Vegetated	Vegetated	Vegetated

Regardless the applied loads, the vegetated bed took 11 weeks until attaining steady-state conditions in terms of COD removal against 3 weeks of the unvegetated bed (assays 1.1 and 2.1). The removal of ammonia nitrogen was unstable during the 80 weeks of operation. During the first 8 weeks, the removal rates of COD and NH_4-N in the vegetated bed were very unstable, but 50% higher than the ones observed in the unvegetated bed. It seems that the continuous growth of roots and rhizomes affected the stabilization and development of the biofilm responsible for removing organic matter and ammonia as also observed by Vymazal and Kropfelova (2008) during bed washout scenarios.

Stabilization of COD removal in the vegetated bed was also observed between weeks 72 and 80 (assays 1.2, 2.2 and 2.3). When the OLR was decreased 45% (from 20 to 10 g COD m^2 d^{-1}) that bed reacted positively removing the entire organic load. However, when the NLR decreased the same percentage (from 2 to 1.1 g NH_4-N m^2 d^{-1}) the removal of ammonia nitrogen decreased approximately 50%. The removal of NH_4-N was more unstable over time without have been observed a stable removal pattern in both beds. These results reflect a more unstable development of nitrifying biofilm and higher sensitivity to changes in incoming loads. There was no detection of NO_2-N and NO_3-N at internal points, which shows the higher reduced conditions in the subsurface stream.

Regardless the applied loads and the bed characteristics (vegetated/unvegetated), the higher removal rates occurred near the feeding point where DO concentrations were higher and

there was no significant plant development. This occurrence shows that atmospheric oxygenation still has a major role on organic matter and ammonia removal than the presence of *Phragmites australis*.

CONCLUSIONS

Regardless the applied loads, HSSF-CW may be affected by *Phragmites australis* growth during the start-up phase. The removal of both ammonia and organic matter were more unstable during the first 8 weeks of operation. After the 11st week of operation the removal of organic matter started to stabilized over time. The removal of ammonia was more unstable over time, what reflects that the development of plants and the changes in operating conditions most significantly influence the ammonia removal mechanisms (e.g. plant uptake and nitrification).

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