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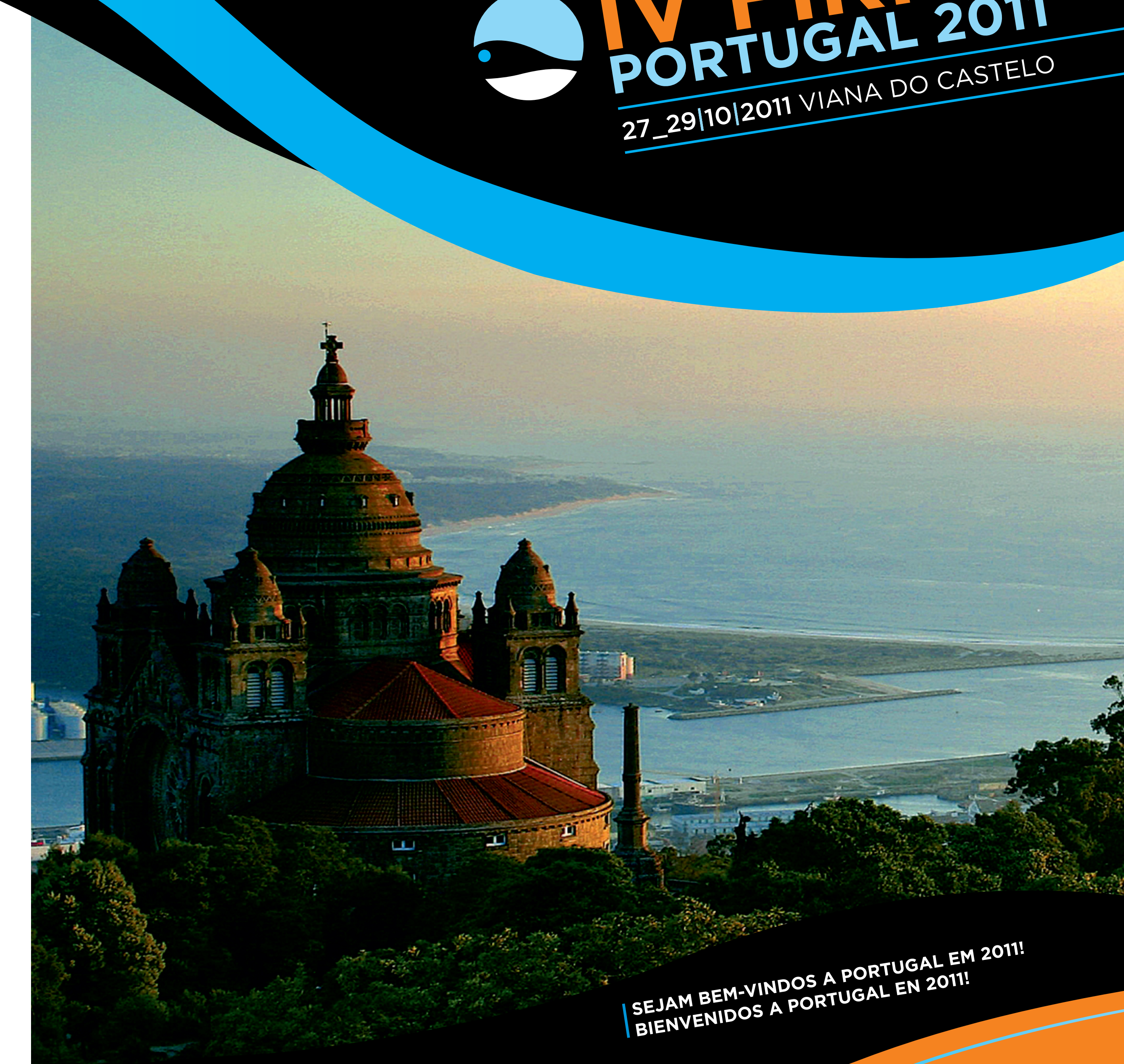

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Constructed Wetlands for freshwater and saline aquaculture wastewater treatment: a microcosm experience

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Abstract

The aquaculture industry discharges large volumes of nutrient rich wastewater, contributing to eutrophication events. Recent culture intensification methodologies such as recirculation (RAS) and shallow raceway (SRS) systems discharge wastewater with even higher nutrient concentrations, though at lower volumes (Rana *et al.*, 2005). Hence, effluent treatment options are of vital importance. Constructed wetlands (CWs) are a possible but underexplored treatment solution even for high salinity situations (Lymbery *et al.*, 2006) consisting of planted shallow channels, relying upon biological, physical and chemical processes to treat wastewater (EPA, 2000). Therefore, this study aims to extend the knowledge on the possible use of CWs for aquaculture wastewater treatment, either fresh or saline.

To fulfill this goal, several microcosms were created simulating subsurface systems with HRT = 7 days and planted with *Typha latifolia*. Substrate used was expanded clay 8 – 12.5 mm Ø. Macrophyte survival, growth, and nutrient removal (phosphate, nitrite, nitrate and ammonia) were assessed over a period of 4 weeks. Freshwater (simulated) and saline (real) fish farm effluents (recirculation SRS, 2.4% salinity) were tested.

Results showed that plants adapted better to freshwater conditions exhibiting higher growth rate. Plants at 2.4% salinity did not growth in height after 2 weeks, but survival remained high.

The microcosm wetland system was able to treat the effluent by removing 61%, 78% and 98% of NH_4, NO_2 and PO_4, respectively, in fresh water, and 94%; 78%, 34% and 100% of NH_4, NO_2, NO_3 and PO_4, respectively, in saline wastewater. An improvement of removal with time was observed, suggesting the existence of a system adaptation period. The microcosm treatment was able to reduce nutrient concentrations to legally acceptable values. Hence, constructed wetlands can be an adequate solution for aquaculture effluent treatment. Further studies are necessary, however, to achieve a better adaptation of the plant used to salinity.

Keywords

Constructed wetland, phytoremediation, aquaculture wastewater, seawater.

Introduction

Aquaculture activity produces wastewater with increasing nutrient loadings due to new intensification practices, putting environmental pressure in the vicinity of the culture farms. This discharge contributes to the degradation of receiving waters, becoming a problem that needs to be addressed. Intensive culture methods, such as recirculation (RAS) and shallow raceways (SRS), increase effluent nutrient concentrations (Rana *et al.*, 2005). However, the unique characteristics of aquaculture wastewaters make their treatment costly and energy intensive. Constructed wetlands are a possible but not much explored treatment solution even for high saline wastewater (Lymbery *et al.*, 2006), consisting of planted shallow channels with aquatic plants, relying upon biological, physical and chemical processes to treat wastewater (EPA, 2000).

The choice of plant is extremely important and must fit a vast list of case-specific criteria, like being native, perennial, flood resistant and able to withstand possible toxic effects of the wastewater (of which salinity is an example). Some macrophytes commonly used in CWs are *Typha latifolia* and *Phragmithes australis*, both considered halotolerant (Crites *et al.*, 2006).

Substrate is equally important as it provides support to the root system of the plants, promotes the establishment of microbial biofilms, and physically adsorbs nutrients (mainly phosphorous). Expanded clay is an inexpensive, non-toxic substrate with high hydraulic conductivity, largely employed in CWs (Calheiros *et al.*, 2009).

This study aims to provide insights to key question marks regarding the use of constructed wetlands to treat freshwater or saline intensive aquaculture wastewater.

Materials and methods

Microcosms were set up indoors, in a naturally well illuminated location, using transparent polypropylene plastic containers with an approximate area of 0.1 m^2 and total volume 10.5 L. The substrate used was expanded clay 8-12.5 mm planted with *T. latifolia* at a density of 30 m^{-2}.

Two sets of microcosms were used in triplicate. The first set was irrigated (HRT = 7 days) with a simulated freshwater aquaculture effluent with initial nutrient concentrations of 0.44 ± 0.11; 3.14 ± 0.09; 0.36 ± 0.01; 1.18 ± 0.06 mg L^{-1} of ammonia ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), nitrite ($N\text{-}NO_2^-$) and phosphate ($P\text{-}PO_4^{3-}$), respectively, as well as several trace elements. The second set of microcosms were planted and irrigated (HRT = 7 days) with aquaculture wastewater from a RAS-SRS aquaculture facility with the following main characteristics: 0.25±0.13; 18.83±8.93; 0.78±0.62; 1.41±0.21 mg L^{-1} of ammonia ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), nitrite ($N\text{-}NO_2^-$) and phosphate ($P\text{-}PO_4^{3-}$), respectively, as well as a salinity 2.43 ± 0.10%. Samples were collected weekly and analyzed for a period of 4 weeks. Macrophyte survival, growth, and nutrient removal (phosphate, nitrite, nitrate and ammonia) were assessed.

Results

Throughout the 4 week experimental period temperature and humidity did not fluctuate greatly and mean values of 23.1 ± 4.7 ºC (n=22) and 51.7 ± 8.2% (n=22), respectively, were observed. Plants were better adapted to freshwater conditions, as expected, with the highest maximum growth values (65 cm after 4 weeks, compared to the 6.5 cm for saline conditions). Plants at high salinity did not growth in height after 2 weeks but revealed high survival rate (close to freshwater specimens) and remained green.

Nutrient concentrations were monitored weekly (except for nitrates in freshwater due to chemical interferences in the technique used) and average nutrient removal percentages were calculated based on the acquired data (Fig. 1).

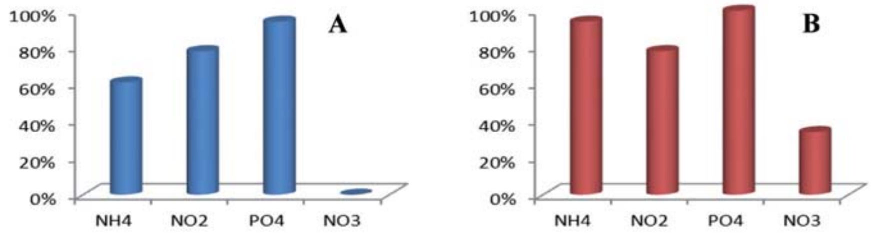

Figure 1.- Nutrient removal (%) in microcosms planted with *T. latifolia* and irrigated with aquaculture effluents from a simulated fresh water system (A: NO_3 not determined) and a saline aquaculture system (B: 2.4% salinity).

Removal rates were similar in both fresh and saline aquaculture wastewater microcosms, with the exception of a slightly higher ammonia removal in saline water. Nitrate removal was low, possibly due to its high initial concentration. PO_4 increased over time, reaching close to 100% removal.

Discussion

Regarding *Typha latifolia* growth, there are several aspects to take into account when assessing plant performance in either fresh or saline water. One of the most important factors can be related to the nutrient composition of the effluents used, which are slightly different, in particular regarding nitrate concentrations, reflecting their different origin. High nitrate and low ammonia concentrations can limit *Typha latifolia* growth (Brix *et al.*, 2002). As for salinity tolerance, our results are consistent with the adaptation strategy of the plant to high salinity, known to remain viable even at very high salinities but with growth inhibition, resuming its growth, at a very high rate, when there are surplus of either nutrients or fresh-water. Still, maximum acceptable values for *Typha latifolia* tolerance are not yet settled in the literature and the results of this study can extend the knowledge on this particular subject.

Concerning nutrient removal rates an adaptation period of 2 to 3 weeks seems to be needed in simulated CWs to enable nitrification, also confirmed in other studies (Calheiros *et al.*, 2009). Substrate is probably the biggest responsible for the elevated phosphate removal observed (Albuquerque *et al.*, 2009).The tested treatment enables nutrient concentration reduction to legal values in accordance with Portuguese laws (D-L nº 348/98 and D-L nº 152/97)

Conclusions

Constructed wetlands can be an adequate solution for aquaculture effluent treatment, achieving nutrient removals able to meet legal standards for discharge wastewater. However, further studies with longer durations are needed for full scale applications.

Acknowledgments

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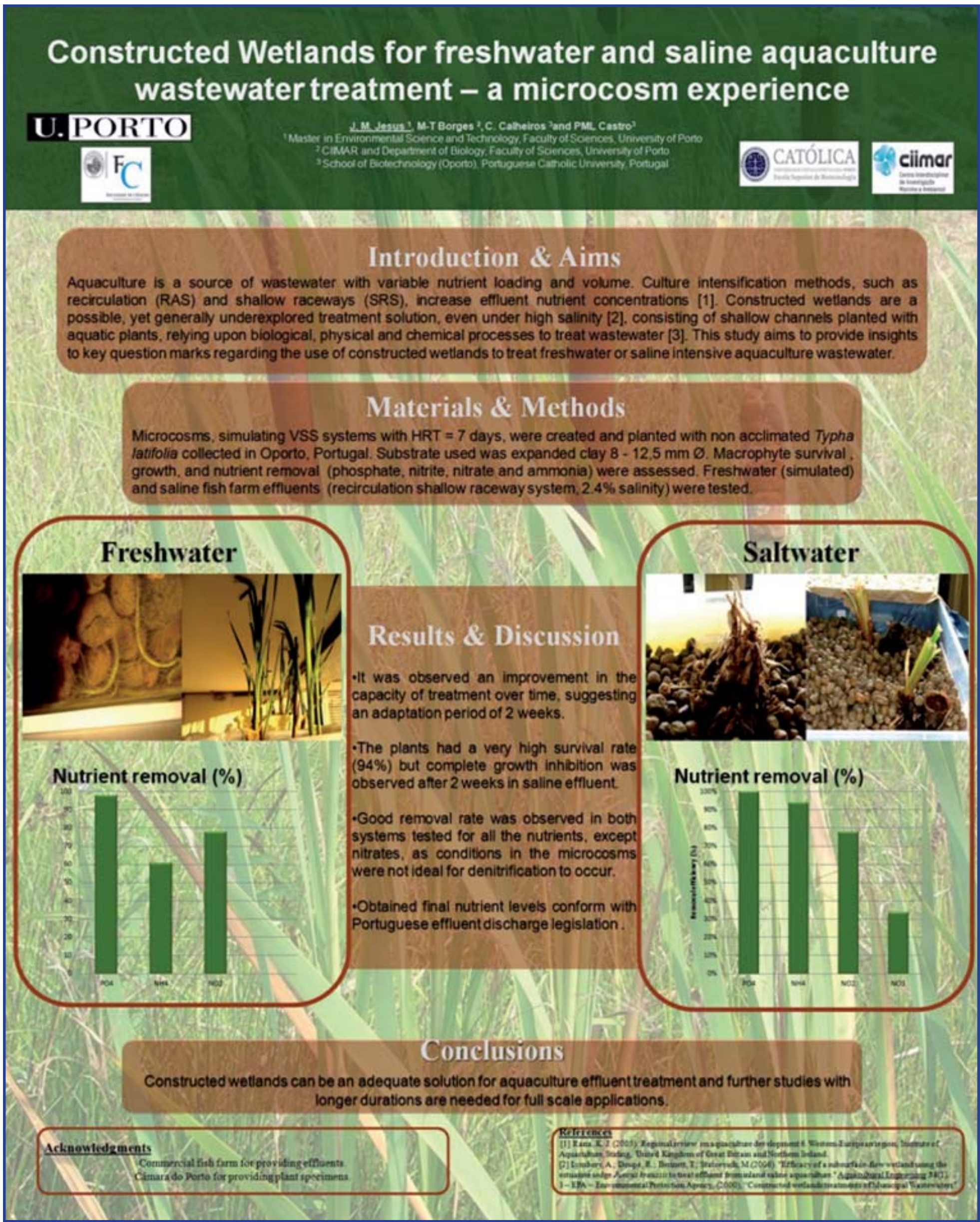

Constructed Wetlands for freshwater and saline aquaculture wastewater treatment – a microcosm experience
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Introduction & Aims
Aquaculture is a source of wastewater with variable nutrient loading and volume. Culture intensification methods, such as recirculation (RAS) and shallow raceways (SRS), increase effluent nutrient concentrations [1]. Constructed wetlands are a possible, yet generally underexplored treatment solution, even under high salinity [2], consisting of shallow channels planted with aquatic plants, relying upon biological, physical and chemical processes to treat wastewater [3]. This study aims to provide insights to key question marks regarding the use of constructed wetlands to treat freshwater or saline intensive aquaculture wastewater.
Materials & Methods
Microcosms, simulating VSS systems with HRT = 7 days, were created and planted with non acclimated Typha latifolia collected in Oporto, Portugal. Substrate used was expanded clay 8 - 12,5 mm Ø. Macrophyte survival, growth, and nutrient removal (phosphate, nitrite, nitrate and ammonia) were assessed. Freshwater (simulated) and saline fish farm effluents (recirculation shallow raceway system, 2.4% salinity) were tested.
Freshwater
Nutrient removal (%)
PO4
NH4
NO2
Results & Discussion
•It was observed an improvement in the capacity of treatment over time, suggesting an adaptation period of 2 weeks.
•The plants had a very high survival rate (94%) but complete growth inhibition was observed after 2 weeks in saline effluent.
•Good removal rate was observed in both systems tested for all the nutrients, except nitrates, as conditions in the microcosms were not ideal for denitrification to occur.
•Obtained final nutrient levels conform with Portuguese effluent discharge legislation.
Saltwater
Nutrient removal (%)
PO4
NH4
NO2
NO3
Conclusions
Constructed wetlands can be an adequate solution for aquaculture effluent treatment and further studies with longer durations are needed for full scale applications.
Acknowledgments
Commercial fish farm for providing effluents.
Câmara do Porto for providing plant specimens
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