PERFORMANCE OF CONSTRUCTED WETLANDS FOR WASTEWATER TREATMENT SUBJECT TO PEAK MASS LOADS

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Abstract

Horizontal subsurface constructed wetlands are considered an appropriate technology for wastewater treatment, particularly for small agglomerations. This study investigates the performance of these systems when subject to peak mass loads and included the implementation of nine experimental constructed wetlands with subsurface horizontal flow which were fed daily with synthetic sewage and monitored during eight months. Weekly samples were collected and analysed regarding COD, pH, temperature, redox potential, dissolved oxygen and electrical conductivity. After applying peak concentration at the inflow, beds showed a COD mass removal rate similar to regular operation conditions; the beds fed with potable water developed biofilm that provided organic matter removal when supplied with synthetic sewage.

Keywords: constructed wetlands, mass removal, chemical oxygen demand, peak loads

Introduction

Constructed wetlands aim to reproduce, in a controlled environment, the phenomena and mechanisms of degradation of pollutants that occur in natural wetlands (Kadlec and Knight, 1996). The implementation and optimisation of these systems depends on the knowledge of natural organic removal processes. Subsurface flow constructed wetlands (SSFCW) consist of four main components: water, soil, plants and microorganisms (Kadlec et al., 2000), and there is a close relationship between them. The removal of any pollutant depends on these four components and involves many mechanisms.

These systems provide treatment efficiencies in organic matter and suspended solids which comply with the discharge limits demanded for a secondary treatment. The complexity of theses systems difficult the understanding of the mechanism and processes involved in the treatment. This justifies the fact that many studies have been and continue to be devoted to analysing the influence of several factors on performance, namely in terms of COD removal. Examples of such factors are concentration, hydraulic loading rate (HLR) and mass loading rate (MLR).

Despite the large number of studies related with HLR and MLR, most of the studies only analyse different steady state conditions and do not refer to the performance during the transition between operating conditions. Although constructed wetlands are recommended to treat effluents from hotels and camping sites, where flow can vary significantly (Masi et al., 2007), the performance of these systems during and after peak conditions is still not fully understood.

This study investigates the performance of constructed wetlands when subject to peak mass loads and included the implementation of nine experimental constructed wetlands with subsurface horizontal flow which were monitored during eight months.

Methods

A laboratory scale experimental installation was set at the Technical Superior Institute, Lisbon, including nine constructed wetlands with subsurface flow horizontal flow (HSSF). Each beds measures 1.2 × 0.8 × 0.76 m. Beds where organized into three groups, A, B and C with each group being composed by three beds: one without vegetation, another colonized by *Phragmites australis*, and the third colonized with *Scirpus*. The beds without vegetation acted as control.

The system was batch fed with an average flow of 10 L/day for each bed, corresponding to a theoretical detention time of seven days. Average water level was 0,25 m, about 5 cm below the surface. Gravel with diameters 4-8 mm was used as filling media, with a porosity of 30%. Feeding was conducted through a perforated pipe inside the bed. A valve at the opposite end of the bed was installed at the bottom to allow a controlled discharge.

The study was carried out from January to July 2010 and was divided into three phases. Phase 1 lasted for 3.5 months during which a constant COD load was applied to each group: group A received 9.3 g/m^2/day, group B received 4.3 g/m^2/day and group C was fed with potable (tap) water to ensure a null COD load. The aim of Phase 1 was to establish the mean mass removal rates provided by each group. Phase 2 lasted 2 weeks and mass load was increase by 20% for groups A and B. Group C received a COD load during this phase of 1.4 g/m^2/day. Phase 3 lasted 4 weeks and the conditions of Phase 1 were restored. Samples of the discharged effluent were collected on a weekly basis. Each sample was analyzed regarding COD while experimental conditions such as temperature, redox potential, pH and dissolved oxygen were also measured *in situ,* twice per week.

Results and discussion

Table 1 presents the mass removal rates obtained for Phase 1, 2 and 3, in each bed.

Table 1. Mass removal rates for Phases 1, 2 and 3.

Group	Bed	Mass removal rate ($g/m^2/day$)		
		Phase 1	Phase 2	Phase 3
A	1	6.4	8.0	6.1
	2	6.5	8.5	6.0
	3	6.2	7.3	6.2
B	4	3.1	2.6	3.1
	5	2.8	2.7	2.7
	6	2.7	4.0	2.9
C	7	−0.2	1.1	−0.1
	8	−0.1	1.1	−0.1
	9	−0.1	1.0	−0.1

During Phase 1 the differences in mass removal within each group were very small. A statistical analysis of the results using ANOVA showed that differences where not statistically significant (p-value<0.05), which indicates that the influence of vegetation inside each group was not significant. On the other hand, differences between groups were relevant indicating that mass removal rates depend on the organic input load. This is consistent with results presented in existing studies (Caselles-Osorio and Garcia, 2007; Chazarenc et al., 2007).

During Phase 2, the adjustment of the bed to higher organic loads occurred after the first week of Phase 2 due to the hydraulic retention time of approximately seven days. Group B could not be fully studied during this phase for the effect of increasing concentrations since the inherent variability of the synthetic wastewater used resulted in COD mean values lower than expected (increase of only 7 % compared to Phase 1).

During Phase 2 groups A and B showed an increase in COD mass removal rates when compared to Phase 1. However, this result may not entirely represent the adjustments of this phase since it was very short and the retention time influenced the response of the system. In fact, the effluent concentrations during this phase increased which showed that the capacity to remove organic matter is possibly limited by the biofilm mass formed during Phase 1.

Group C showed a positive mass removal during Phase 2. The rapid response of beds 7, 8 and 9 to the increased organic loads may indicate the presence of an established microbial community during feeding with tap water. This phenomenon can be compared to a similar one observed in sand filters used for water treatment for human consumption (Urfer and Huck, 2001).

The results presented in Table 1 show that mass removal rates obtained for Phase 3 were similar to Phase 1. Due to the reduced monitoring period few values were considered in the calculation, taking into account only the last values were there was no influence from Phase 2. These results seem to indicate that the biofilm established during Phase1 was maintained through the rest of the study and as initial concentrations resume so was the performance.

Conclusions

Possible differences in performance between subsurface horizontal flow constructed wetlands (SSFCW) can be attributed to different organic input load, particularly during load peaks.

The present study was intended to provide a contribution to understand the performance of constructed wetlands subject to peak loads in terms of COD. During stable (non-peak) input conditions, results show that vegetation was not relevant for the COD removal for a given organic load mass. This could be due to the fact that vegetation did not complete a full vegetative cycle.

When submitted to mass peak loads the beds showed higher values of COD output concentrations in comparison with Phase 1 accompanied by an increase in mass removal. When peak loads ended and regular mass loads where resumed the obtained mass removal was also similar to the initial conditions. The study also showed that constructed wetlands fed with tap water can provide organic matter removal. This seems to indicate the presence of a microbial community established even without organic matter input.

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