Evaluation of the relative importance of microbial reactions on COD removal in HSSF CWs treating wastewater rich in nitrates: CWM1-RETRASO simulations

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INTRODUCTION

A large number of studies have demonstrated that organic matter and total solids removal in horizontal subsurface flow constructed wetlands (HSSF CWs) is due to physical and chemical processes that retain and entrap particulate matter in the wetland matrix (Pedescoll et al., 2009). Biological processes, in turn, are responsible for the degradation of solids retained in the granular medium and of dissolved organic matter, nitrogen, and sulphur compounds. The scientific community now accepts that in HSSF CWs this degradation occurs through several biochemical pathways, which can take place at the same time but at different locations (García et al., 2005; Faulwetter et al., 2009). However, the relative importance of biochemical pathways may change over time and space depending on some factors (e.g. hydraulic loading rate (HLR), redox potential and availability of terminal electron acceptors). Modelling, especially mechanistic mathematical models, has become a powerful tool to better understand the performance of wastewater treatment systems.

The aim of the present contribution was to evaluate the relative contribution of the microbial reactions considered in CWM1-RETRASO model on organic matter removal (in terms of COD) in HSSF CWs treating urban wastewater rich in nitrates.

METHODS

CWM1-RETRASO simulation model

CWM1-RETRASO model (Llorens et al., 2009, 2010) is a 2D mechanistic mathematical simulation model obtained from the implementation of CWM1 (Langergraber et al., 2009) in RCB code. Within CWM1-RETRASO, RCB provides the knowledge related to reactive transport and flow properties while CWM1 provides that related to biochemical processes.

Approaches definition

Three different approaches were simulated, in which diverse influent configurations were considered (Table 1).

Table 1. Influent composition of the scenarios simulated. The components description can be found in Langergraber et al. (2009).

Scenarios					Scenarios				
Components [units]		1	2	3	Components [units]		1	2	3
S_F	[mg O_2/L]	195	0	23	X_I	[mg O_2/L]	0	0	3
S_A	[mg O_2/L]	0	195	6	X_S	[mg O_2/L]	0	0	26
S_I	[mg O_2/L]	0	0	3	S_{SO4}	[mg S/L]	0	0	47
S_{NO}	[mg N/L]	12	12	12	S_{NH}	[mg N/L]	0	0	9

Approaches were all based on theoretical assumptions; however, approach 3 was more realistic, because it was based on some experimental observations from the effluent of a vertical subsurface flow constructed wetland (VSSF CW). Accordingly, the aim of approach 3 was to consider an influent similar to wastewater previously treated in a VSSF CW. The scenarios were based on a real HSSF CW, C1, located at a pilot plant in Les Franqueses del Vallès (province of Barcelona, Catalonia)(García et al., 2005). C1 was designed with an aspect ratio of 2:1, coarse granitic gravel and average wetted depth of approximately 0.5 m.

RESULTS AND DISCUSSION

Anaerobic processes (methanogenesis and sulphate reduction) were more widespread in the wetland and contributed to a higher COD removal rate (59-77%) than anoxic (denitrification; 3-19%) and aerobic reactions (20-26%) did (Table 2). In all the cases simulated, the reaction that most contributed to COD removal was methanogenesis (46-76%). The results related to aerobic processes are in agreement with those of Llorens et al. (2010) (20-27%), who also used CWM1-RETRASO to simulate wastewater biodegradation and transformation processes within the wetland C1. In this work, wastewater used as influent had not nitrates. On the other hand, in the present study, anoxic processes contributed to a higher COD removal rate in comparison with results of Llorens et al. (2010) due to the entrance of nitrates in the influent (from 0-1% to 3-19%). The highest percentage values for anoxic respiration were observed in the scenario 3 (Figures 1-2), where organic matter was mainly constituted by S_F and S_A. When organic matter was only constituted by S_A these percentage values were the lowest and the highest for methanogenesis. This led to think that methanogenic and denitrifying bacteria competes for S_A (Figures 1-2). The maximum contribution of sulphate reduction process was given in scenario 3, which represented a more realistic case (with sulphate).

Table 2. COD removal percentage by the considered microbial reactions for each scenario.

Scenarios / Percentage [%]	1	2	3
Aerobic processes	25.74	20.35	22.30
Denitrification	7.00	3.18	18.71
Methanogenesis	66.49	75.72	46.10
Sulphate reduction	0.77	0.75	12.89

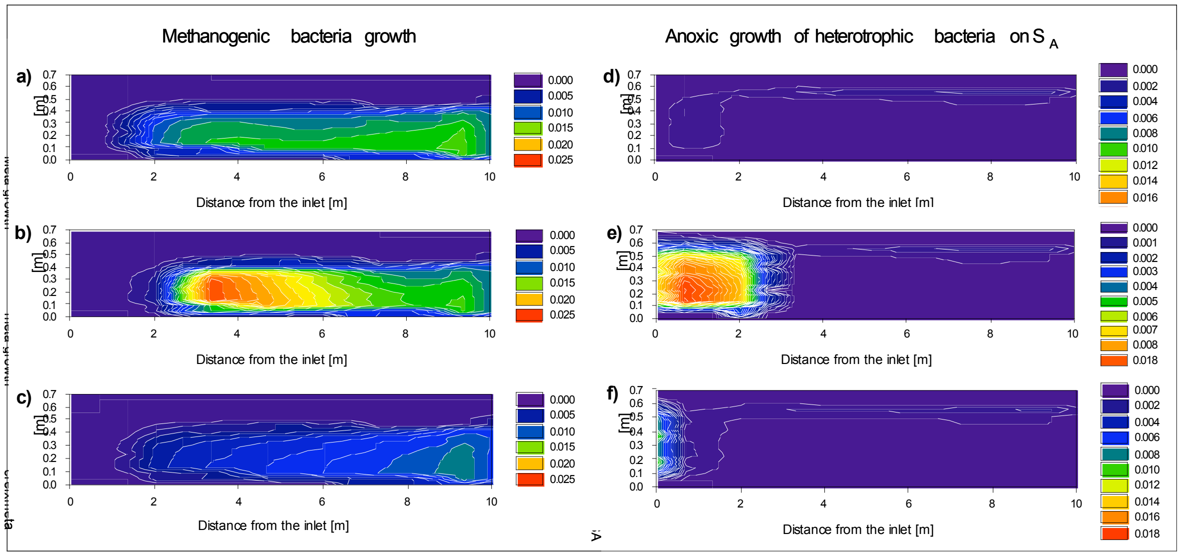

Figure 1. Simulated changes along the length of the wetland of the rates [mol substrate/ 8.4E5 s · kg water] of the growth processes of methanogenic and denitrifying bacteria on S_A for scenarios 1 (a, d), 2 (b, e) and 3 (c, f). Each image contains the mesh of the model that represents a longitudinal profile of the wetland, with a length of 10 m and a depth in the inlet of 0.6 m and in the outlet 0.7 m (vertical axis).

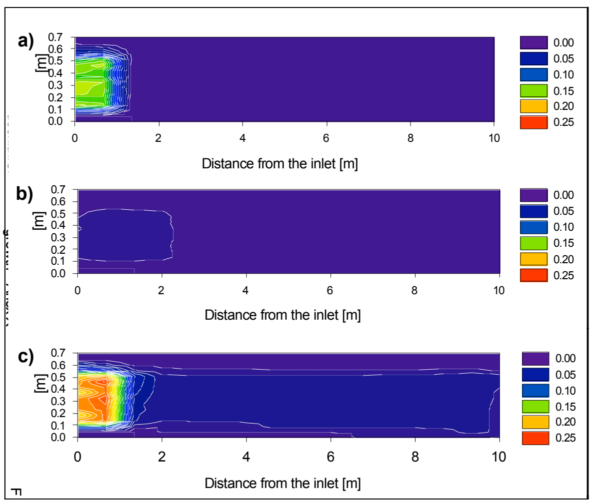

Figure 2. Simulated changes along the length of the wetland of the rates [mol substrate/ 8.4E5 s · kg water] of the growth process of denitrifying bacteria on S_F for scenarios 1 (a), 2 (b) and 3 (c). Each image contains the mesh of the model that represents a longitudinal profile of the wetland, with a length of 10 m and a depth in the inlet of 0.6 m and in the outlet 0.7 m (vertical axis).

Results agree with those found by recent studies, which have shown that aerobic respiration plays only a minor role or is just one of many microbial reactions that contribute to the overall organic matter decomposition (Baptista et al., 2003). Moreover, the relevant role of methanogenesis found in this study is confirmed by recent studies on methane emissions from HSSF CWs (Picek et al., 2007).

CONCLUSIONS

The good simulation predictions suggested CWM1-RETRASO as a powerful tool to gain insight into HSSF CW treatment processes.

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