Modeling Bioclogging Effects in Constructed Wetlands for Wastewater Treatment

R. Samso[1], N. Forquet[2], P. Molle[2], J. Garcia[1]

[1]Department of Hydraulic, Maritime and Environmental Engineering, Universitat Politècnica de Catalunya-BarcelonaTech, Barcelona, Spain
[2]IRSTEA, Freshwater Systems, Ecology and Pollution Research Unit, Villeurbanne, France

Abstract

Horizontal-Flow Constructed Wetlands (HFCWs) are a particular type of biofilter, and as such they rely mostly on the activity of bacterial communities to treat wastewater. Bacterial growth in HFCWs induces dramatic changes in its hydraulic and hydrodynamic behaviour (bioclogging), which may eventually result in overland flow of wastewater. Consequently, clogging is the main cause of premature failure of HFCWs.

The objective of the present work is to study bioclogging development and its effects on the general functioning of HFCWs.

Results will help understanding bioclogging dynamics in HFCWS and hence may lead to significant operational cost reduction, performance improvement and longer system life-span.

COMSOL Multiphysics® Subsurface Flow module was used to model unsaturated flow and the reactive transport of a pollutant (S) through the domain shown in Figure 1. Overland flow was approached using the Richards equation which is only valid under certain conditions.

Monod expressions were implemented as PDEs to represent the growth of an ideal bacteria group (X) and its effect on the concentration of S.

Rozensweig et al., (2009) formulation, based on the capillary model, was used to calculate the effects of bacteria induced pore diameter reduction over time on the hydraulic conductivity and water retention. These equations were implemented in MATLAB®, and Livelink™ for MATLAB® was used to exchange data with COMSOL Multiphysics®.

Two simulations were run, one considering porosity reduction caused by bioclogging and one neglecting it. Quantitative and qualitative comparisons were made between the results of the two simulations.

When considering porosity reduction, the hydraulic conductivity of the subsurface environment rapidly decreased, forcing water overland (Figure 2), giving the elongated shape of bacteria seen in Figure 3 (left) and displacing the center of masses of bacteria within the bed (Figure 4).

When bioclogging effects were not considered bacteria progressed uniformly from inlet to outlet at a slower pace than when bioclogging effects were accounted for.

Bacterial communities modify the hydrodynamic behavior of HFCWs. When considering bacteria induced porosity reduction, bacteria progressed faster towards the outlet than when bioclogging was not considered. Neither effluent concentrations nor porosity occupation changed when including clogging effects (results not shown). Results of this study indicated that considering bioclogging effects is essential to obtain realistic results when simulating the general functioning of HFCWs. They may also explain why rapid system failure is sometimes observed when overland flow starts developing.

Reference

Rosenzweig, R., Shavit, U., Furman, A., 2009. The Influence of Biofilm Spatial Distribution Scenarios on Hydraulic Conductivity of Unsaturated Soils. Vadose Zone Journal 8, 1080-1084.
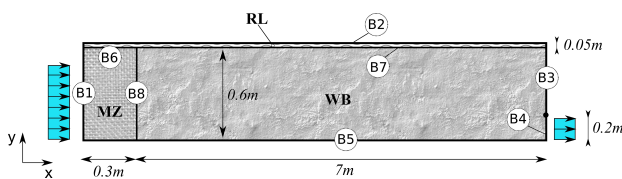
Figures used in the abstract

Figure 1: Model domain. MZ represents the mixing zone, RL the runoff layer and WB the wetland body. B1 and B4 are inlet and outlet boundaries, respectively.
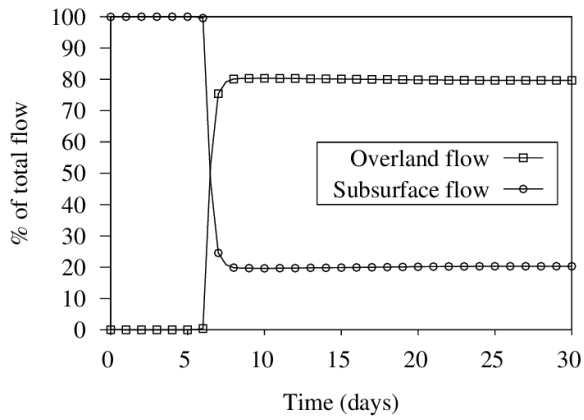
Figure 2: Percentage of the total flow passing through boundary B4 (Overland flow) and that passing through boundary B8 (Subsurface flow).
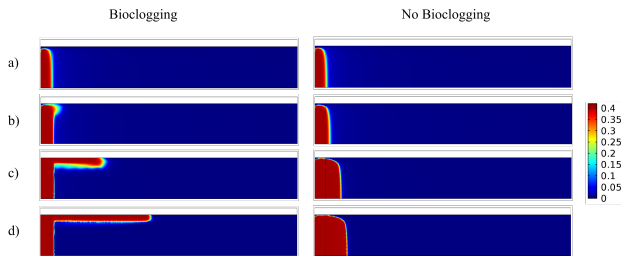

Figure 3: Bacteria concentration (mgCODL-1) within a longitudinal section of the wetland with and without bioclogging after (a) 5 days, (b) 6.5 days, (c) 15 days and (d) 30 days.
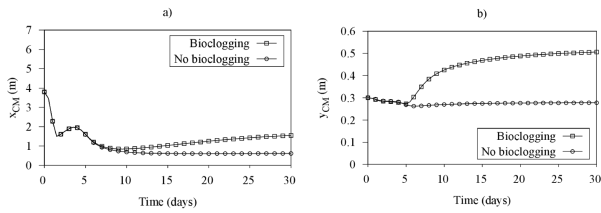

Figure 4: Centre of masses of bacteria in the x (a) and y (b) axes.