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Removal of bacterial and viral indicators in horizontal and vertical subsurface flow constructed wetlands

A. Torrens[a], M. Folch[a]; J. Sasa[a]; M. Lucero[a], E. Huertas[a], P. Molle[b], C. Boutin[b] and M. Salgot[a]

[a]Soil Science Laboratory, Faculty of Pharmacy, University of Barcelona, Avda, Joan XXIII s/n 08028, Barcelona, Spain (E-mail: antoninatorrens@ub.edu)
[b]Cemagref, Water quality and pollution prevention research team, 3 bis quai Chauveau CP 220 69336 Lyon Cedex 09, France

Abstract
Subsurface horizontal flow constructed wetlands (HFCW) and vertical flow constructed wetlands (VFCW) have been compared regarding their efficiencies on microbiological indicators removal. Seven types of HFCWs and two types of VFCWs have been monitored for several years. Fecal coliforms, *E. coli*, somatic coliphages and F-specific bacteriophages were analyzed in the influent and effluents of each system. All constructed wetlands monitored were planted with *Phragmites australis* but have different design characteristics and operation variables. All data were statistically treated (SPSS v17) in order to analyse the effect of design and operation variables on each microbiological indicator. VFCWs were more efficient than HFCWs systems when considering removal rates per surface for all the microbiological indicators (cfu or pfu removed/m^2.d). Nevertheless, considering mean removal efficiencies (in log units), results did not show statistically significant differences. The hydraulic retention time was the key parameter regarding filter disinfection capacity in both types of filters. Bacterial indicators were removed at a higher rate than viral indicators.

Keywords
Bacterial indicators, horizontal flow, vertical flow, viral indicators, wetlands, wastewater treatment and reuse

INTRODUCTION

Removal of pathogenic indicators from wastewater is one the most important concern when establishing a wastewater treatment system if the effluent is intended to be reused. The capacity of free surface or horizontal subsurface flow constructed wetlands (HFCWs) to remove bacterial indicator microorganisms has been thoroughly examined. However, few studies have addressed the disinfection effectiveness of vertical flow constructed wetlands (VFCWs). The processes involved in bacterial decay for both type of systems are different as the hydraulic regime has a direct impact in bacterial removal mechanisms. Additionally scarce literature is available on the fate of viral indicators in subsurface flow constructed wetlands (SSFCWs) treatment.

MATERIAL AND METHODS

Seven types of HFCWs and two of VFCWs have been monitored for several years. Fecal coliforms (FC), *E. coli*, somatic coliphages (SC) and F-specific bacteriophages (FsB) were analyzed in the influent and effluents of each system. All constructed wetlands (CWs) monitored were planted with *Phragmites australis.* The configuration and design parameters of the CWs are summarised in Table 1. All data obtained were statistically treated with SPSS v17.

Table 1. Main configuration and design and operation characteristics of the SSFCWs.

Site	Flow[a]	Type of treatment[b]	Number of cells	Cell surface (m^2)	Depth (m)	HL[c] (m/d)	Filtering media	Medium size[d] (mm)	Operation[e]
Besòs	H	T (AS)	60	1436[f]	0,6-0,8	0,25	Gravel	6-25	C
Hostalets de Pierola	H	S (IT)	1	800	0,6-1	0,05	Gravel	2-15	C
	H	S (IP)	1	800	0,6-1	0,05	Gravel	2-15	C
Corbins	H	S (IT)	2	1225	0,6-0,8	0,08	Gravel	10-20	C
Verdú	H	S (ST)	4	1105	0,6-0,8	0,04	Gravel	8-12	C
	H	T (P)	2	518	0,6-0,8	0,17	Gravel	8-12	C
Sant Martí	H	S (ST)	2	1513	0,6-0,9	0,09	Gravel	3-10	C
Aurignac	V	T (P)	1	50	0,65	0,6	Sand	d_{10} 0,25; CU 4,7	I,R
	V	T (P)	1	50	0,25	0,6	Sand	d_{10} 0,25; CU 4,7	I,R

[a]H: Horizontal, V: Vertical; [b]T: Tertiary, S: Secondary; (previous treatment): AS: Activated Sludge, IT: Imhoff Tank, IP: Infiltration Percolation, ST: Septic Tank, P: Pond; [c] HL: average hydraulic load, [d]d_{10}: Mesh diameter allowing 10% of the sand mass to go through (mm), CU: Coefficient of uniformity: ratio d_{60}/d_{10}; [e]C: Continuous loading, I: Intermittent loading, R: Resting periods; [f]Cell surface average

RESULTS AND DISCUSSION

The average removal for all the indicators was always less than 2 log units despite the type of CW (Figure 1). The effectiveness of the HFCWs when operating as secondary effluent is better compared to the tertiary, because the removal of microbial indicators is higher at higher loads. Viral indicators (mainly FsB) were more resistant than bacterial indicators in all type of systems, confirming that removal mechanisms of virus and bacteria are different in CWs. Considering mean removal efficiencies (log units) for tertiary treatment, results do not show statistically significant differences between VFCWs and HFCWs for any microbial indicator despite the higher Hydraulic Retention Time (HRT) of the HFCWs. Moreover, as shown in Figure 1, VFCWs are more efficient when considering surface removal rates (CFU or PFU removed/m^2/d). VFCWs operating as primary or secondary present average removals around 1,5 log units (Arias *et al.*, 2003; Abidi *et al*; 2009). Other than filtration, mechanisms such as protozoa predation and endogenous respiration may play an important role in the removal of microbial indicators in CWs. These last two mechanisms would be enhanced in VFCWs as the conditions in the filters are different (oxygen content, humidity...).

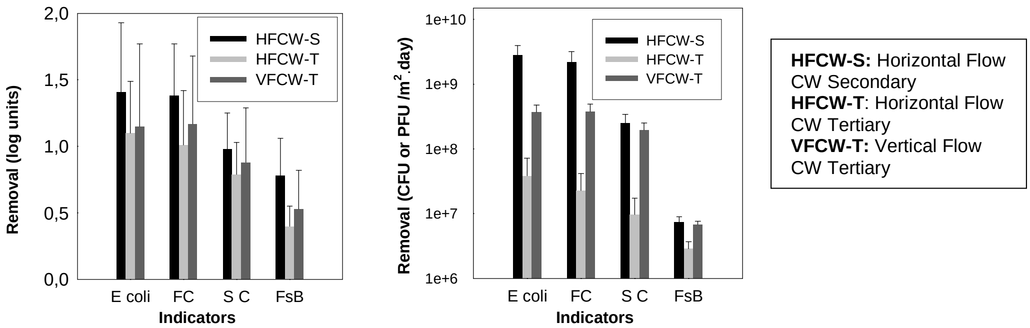

Figure 1. Mean removals of microbial indicators (log units and surface removal rates).

Media granulometry, HL, filter depth and volume per dose significantly affect the removal of bacterial indicators as all these factors have a direct effect on HRT (Torrens *et al.;* 2009). Removal of microbial indicators in both VFCWs and HFCWs is a function of the HRT (Figure 2). For both VFCWs and HFCWs microbial inactivation tends to be asymptotic (mainly for HFCWs). Therefore, after a certain value an increase of HRT will not result in a significant higher removal.

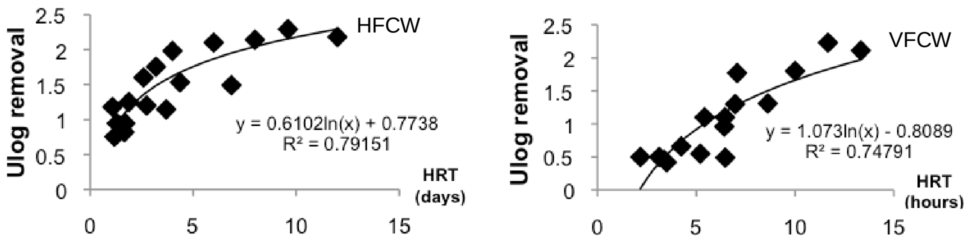

Figure 2. *E. Coli* removal (Ulog) plotted against HRT for HFCW and VFCW.

CONCLUSIONS

Removal of microbial indicators in VFCWs and HFCWs is similar considering mean removal efficiencies (in log units). Nevertheless, VFCWs are more efficient than HFCWs when considering surface removal rates (cfu or pfu removed/m^2.d). The choice of the technology will therefore mainly depend on the available space, the costs and the technical capacity of construction and operation. HRT is the key parameter regarding filter disinfection capacity in both types of CWs. Bacterial indicators are removed at a higher rate than viral indicators.

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