INFLUENCE OF PLANT SPECIE, MEDIA SIZE AND FLOW MODEL ON THE PERFORMANCE OF SUBSURFACE CONSTRUCTED WETLANDS TREATING MUNICIPAL WASTEWATER

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ABSTRACT

A pilot plant was built to investigate the treatment of municipal wastewaters in subsurface constructed wetlands (CW) regarding the effect of plant species, granular media size and flow direction. Average hydraulic loading rates applied were 26-28 mm/d for horizontal flow (HF) units and 114 mm/d for vertical flow units, while surface loading rates were about 5 and 20 g COD/m^2·d for HF and VF units, respectively. Removal efficiency was near 90% for HF units, without significant differences regarding the plant specie. However, at the applied conditions, efficiency significantly decreases for VF units in comparison to HF units. Furthermore, finest granular media in VF units showed better efficiencies but at no significant level.

MATERIALS AND METHODS

The field pilot plant was constituted of an up flow anaerobic digester (UASB) as pre-treatment followed by several CW units in parallel, as indicated in Figure 1. Five subsurface horizontal flow (HF) units were used to study the effect of the kind of macrophite used (HF1: no vegetated, HF2: *Juncus effusus,* HF3: *Iris pseudacorus,* HF4: *Thypha latifolia* and HF5: *Phragmites australis*). Two additional vertical flow (VF) units, planted with *Phragmites australis* allowed comparing between horizontal and vertical flow options and between media materials (VF1: sand 1-3 mm, VF2: fine gravel 3-6 mm). The influent to the plant comes from a local sewer receiving wastewaters from one of the faculties of the University of A Coruña and surrounding houses.

Each HF unit have an overall surface of 12 m2 (3 m large x 4 m long) and gravel media (6-12 mm in size) depth of 35 m (0.3 m of water depth). FV units have a surface of 3 m2 and were constituted for a drainage bed of 20 mm large gravel (of about 20 cm at the bottom) and an upper filtering bed of sand or fine gravel (about 80 cm).

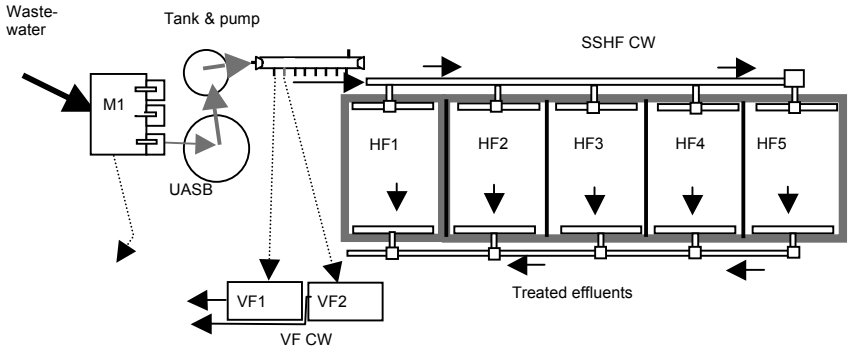

Figure 1. Scheme of pilot plant with five horizontal flow (HF) and two vertical flow (VF) units working in parallel.

Three sampling campaigns were carried out to determine the operational characteristics and performance of each CW unit. The pilot plant was fed for about 12 to 14 h per day and five days at week. Sampling procedures involved to take influent composite samples (integrated over a 24 h period) and daily effluent grab samples. This procedure was repeated once at week (usually from Wednesdays to Thursdays) during a period of four to six weeks at each campaign.

Obtained samples were analysed in the laboratory for total and volatile suspended solids (TSS, VSS), total chemical oxygen demand (TCOD) and biological oxygen demand (BOD_5). Temperature, pH, oxidation-reduction potential (ORP) and dissolved oxygen were determined in situ at the same sampling days.

RESULTS AND DISCUSION

The characteristics of the municipal wastewater fed to the pilot CW wetland are indicated in Table 1. This wastewater was much diluted although during the third sampling campaign TCOD and BOD_5 reached concentrations usually applying for diluted municipal wastewater.

Table 1. Characteristics of the municipal wastewater fed to the CW pilot plant

Campaign (Operation days)	pH	T (°C)	TSS (mg/L)	VSS (mg/L)	TCOD (mg O_2/L)	BOD_5 (mg/L)
I (0-42)	7.2	15.8	55	44	100	57
II (126-146)	7.2	12.7	45	41	164	99
III (223-245)	7.3	19.2	62	58	279	121

Each CW unit was fed with an influent flow of about 0.24-0.36 m^3/d over the entire operational period, generating hydraulic loading rates (HLR) in the range of 20-30 mm/d (HF units) and 105-120 mm/d (VF units). Average HLR and surface loading rates for the three monitoring campaigns are indicated in Table 2 together with the removal efficiency for the main organic parameters. As an example, the TCOD SLR

for the different units and campaigns is shown in Figure 2. HLR was mainly maintained constant while SLR increases from campaign I to III due to the increase in influent concentration (Table 1). However, similar values of HLR and SLR were maintained for HF units at each campaign, while those HLR and SLR values for VF units were about 4 times higher than for HF units.

Table 2. Performance of different constructed wetlands treating municipal wastewater: average values for campaigns I, II and III.

	HF1	HF2	HF3	HF4	HF5	VF1	VF2
Plant	Unplanted	*Juncus effusus*	*Iris pseudacorus*	*Thypha latifolia*	*Phragmites australis*	*Phragmites australis*	*Phragmites australis*
HLR (mm/d)	25,6	28,3	27,6	26,7	28,1	113,8	113,7
Surface loading rate (SLR, $g/m^2.d$)							
TSS	1,4	1,5	1,5	1,4	1,5	6,1	6,1
TCOD	4,4	5,0	4,9	4,7	5,0	20,2	20,1
BOD_5	2,3	2,6	2,5	2,4	2,6	10,4	10,4
Removal efficiency (%)							
TSS	86,2	90.3	90,8	94,0	92,6	82,3	75,8
TCOD	87,5	84,9	86,3	89,5	87,8	73,3	68,6
BOD_5[a]	94,0	95,7	92,4	94,6	94,1	85,4	73,8

[a]Average only for campaigns I and III (BOD_5 data from campaign II was not used as BOD_5 values higher than TCOD, indicating nitrification oxygen demand, were obtained in some samples).

The three campaigns were carried out during the first operational year. During this time, it was observed that both HF and VF wetlands with reeds (*Phragmites australis*) present very low plant densities, in comparison with the other planted beds, so the study must continue for a new growing season in order to obtained definitive results. Provisional data suggest that little differences were found between planted and unplanted beds, and between beds with different species. On the other hand VF CW received a SLR higher than that of HF CW: the same flow and the same amount of organic load were treated in 12 m^2 of each HF unit or in only
3 m^2 of VF units. In these conditions, percent TSS, COD and BOD_5 removals in VF were slightly lower than those obtained for HF units, especially for the VF bed containing the largest gravel.

Figure 2. Total COD SLR for the different units and campaigns

Table 3 shows the results of an analysis of variance, indicating that performance differences were found between HF and VF units. Significant differences for HF units planted with different plant species were not found, except for the pair HF1 and HF4 in removing VSS. On the other hand, all HF units performed significantly better than VF beds at the operational conditions. VF1 containing the finest gravel media performed better than VF2 although significant differences were only found for BOD5 removal efficiency. Regarding effluent dissolved oxygen (DO) concentration and oxidation-reduction potential (ORP), VF units showed more oxygenated and less anaerobic effluents at a significant level.

Table 3. Pair comparison trough one way ANOVA for percent removal of selected parameters and effluent OD concentration and ORP (media of the three campaigns).

Pair	%TSSr	%VSSr	%TCODr	%DBO_5r	OD (mg/L)	ORP (mV)
HF1 - HF2	-4,1	-5,8	2,6	-1,7	0,11	8
HF1 - HF3	-4,6	-6,3	1,2	1,6	0,22	13
HF1 - HF4	-7,8	*-9,7	-1,9	-0,6	0,01	2
HF1 - HF5	-6,4	-7,6	-0,3	-0,2	0,16	16
HF1 – VF1	3,9	3,6	*14,3	*8,6	*-2,02	*-130
HF1 – VF2	*10,3	*9,9	*19,0	*20,2	*-2,02	*-152
HF2 - HF3	-0,5	-0,5	-1,4	3,3	0,11	5,0
HF2 - HF4	-3,7	-3,9	-4,5	1,1	-0,10	-6
HF2 - HF5	9,0	-1,8	-2,9	1,6	0,05	8
HF2 – VF1	8,0	*9,4	*11,6	*10,3	*-2,13	*-137
HF2 – VF2	*14,5	*15,7	*16,3	*21,9	*-2,13	*-160
HF3 - HF4	-3,2	-3,4	-3,1	-2,2	-0,21	-11
HF3 - HF5	-1,8	-1,2	-1,5	-1,7	-0,06	3
HF3 – VF1	8,5	*10,0	*13,0	*7,0	*-2,24	*-142
HF3 – VF2	*14,9	*16,2	*17,7	*18,7	*-2,24	*-165
HF4 - HF5	1,4	2,1	1,6	0,5	0,15	14
HF4 – VF1	*11,7	*13,3	*16,2	*9,2	*-2,03	*-132
HF4 – VF2	*18,1	*19,6	*20,9	*20,8	*-2,03	*-154

HF5 – VF1	*10,3	*11,2	*14,5	*8,7	*-2,18	*-145
HF5 – VF2	*16,8	*17,5	*19,2	*20,4	*-2,18	*-168
VF1 – VF2	6,4	6,3	4,7	*11,7	0,0	-23

*Indicates significant (95% confidence level) differences between pairs

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