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AEROBIC AND ANAEROBIC BIODEGRADABILITY OF ACCUMULATED SOLIDS IN HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLANDS

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INTRODUCTION

Solids accumulation in CWs

- Constructed wetlands (CWs) require to be properly designed and maintained
- Clogging of granular media is one of the main problems of subsurface flow CWs
- Clogging reduces the infiltration capacity and porosity of the gravel bed, and deteriorates the treatment efficiency and system longevity
- Clogging is due to the accumulation of different type of solids, such as undegraded wastewater solids, microbial biofilm and plant detritus
- Solids accumulation can be affected by surface loading rate, but also by solids biodegradation rate
- Macrophytes, which play several beneficial roles in CWs, can affect clogging in several ways

HSSF CWs are mainly anaerobic systems, but anaerobic biodegradability of accumulated solids was not found in literature

Besides, the effect of enhanced aeration on clogging process remains unclear

INTRODUCTION

Objectives

- to determine the accumulation of solids in HSSF CWs planted with different macrophyte species
- to determine biodegradability characteristics of accumulated solids
- to compare aerobic and anaerobic degradation rates of solids
- to answer if promoting aerobic conditions increases or reduces clogging risk.

Solids accumulation and related clogging parameters (i.e. hydraulic conductivity and drainable porosity) were assessed regarding the following factors:

- the presence or absence of vegetation
- the plant species (*Juncus effusus*, *Iris pseudacorus, Thypha latifolia L.* and *Phragmites australis*)
- the loading rate applied

MATERIALS AND METHODS

HF1: Unplanted

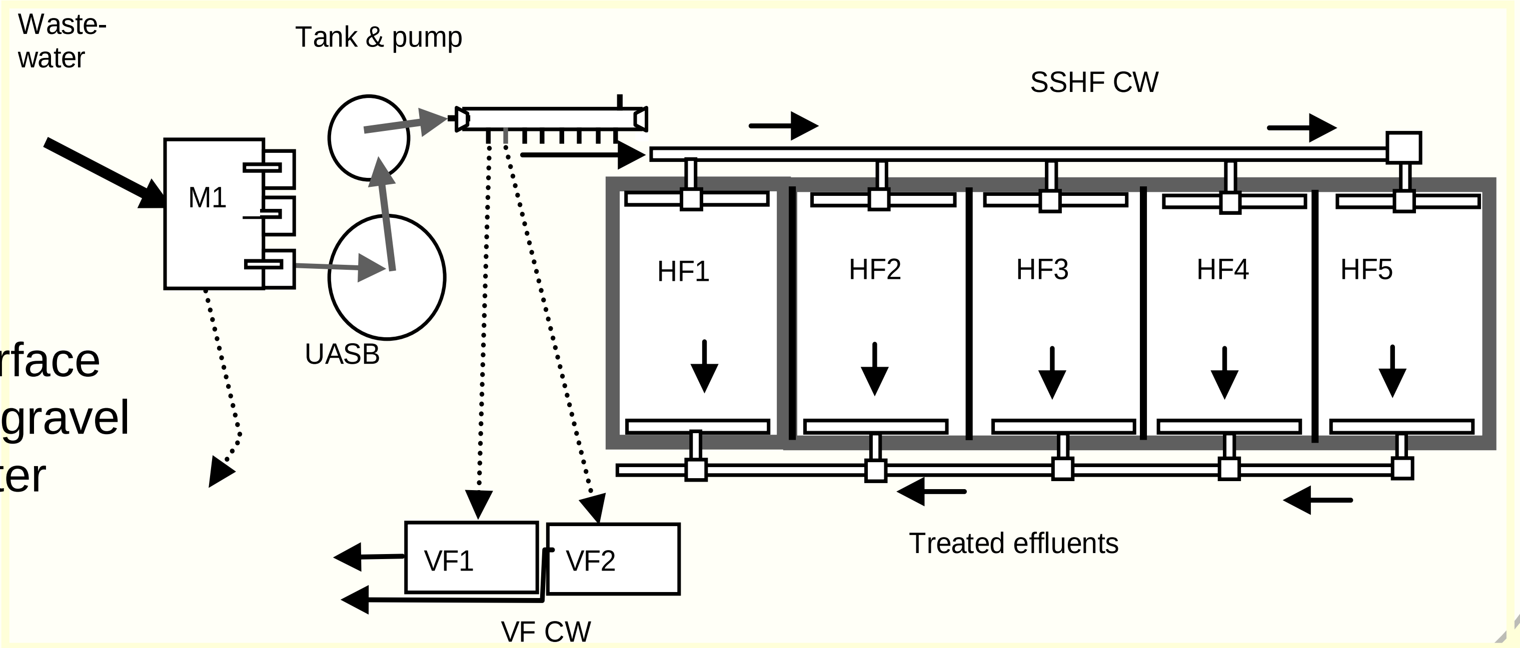
HF2: Juncus effusus

HF3: Iris pseudacorus

HF4: Thypha latifolia

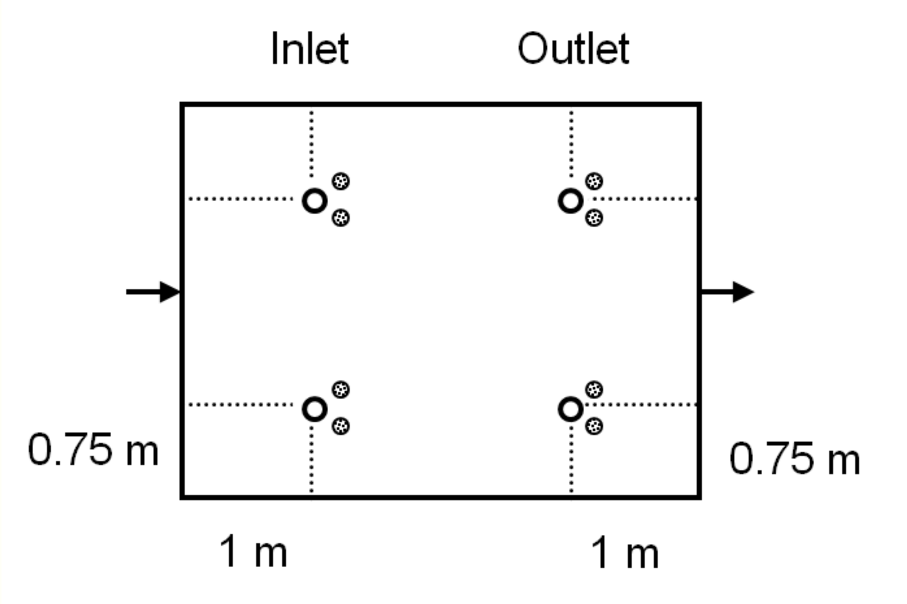
HF5: Phragmites australis

Pilot plant



12 m2 surface
6-12 mm gravel
0.3 m water depth

MATERIALS AND METHODS



Sampling points

- solids sampling: open circles
- hydraulic conductivity: dotted circles

- Four sample points, inlet and outlet composite samples
- Solids extraction to a water suspension
- Parameters: TS, VS, COD, aerobic biodegradability by means of biological oxygen demand (BOD) assay, and anaerobic biodegradability (ABD) by means of methane production potential assay.
- Hydraulic conductivity: falling head method.
- Drainable porosity: empting the beds

MATERIALS AND METHODS

Biological assays:

Aerobic assays: g O_2 g^{-1} VS

- 525 mL BOD_5 bottles
- BOD curve for a period of 44 days that gives:
- the BOD_5
- the ultimate BOD at 44 days (BOD_L)
- and the BOD profile in time

ABD assays: g COD-CH_4 g^{-1} VS

- 50 mL of liquid in 126 mL of total volume
- 3 g VS L^{-1}
- monitoring: head-space gas analysis method (gas chromatography)
- incubation time: until the cumulative methane production stopped rising.

Above-ground biomass determination (and harvesting)

MATERIALS AND METHODS

Measurement campaigns and conditions of plant operation and efficiency

Campaign (days)[a]	HLR[b] (mm d^{-1})	SLR[b] (g m^{-2} d^{-1})				Removal (%)[b]			
		TSS	COD	BOD_5	TN	TSS	COD	BOD_5	TN
I (495-543)	25.7±0.6	1.7±0.5	5.0±1.4	2.5±0.8	1.4±0.7	89-93	83-88	90-95	29-52
II (809-900)	22.5±0.8	0.8±0.3	7.2±0.7	4.7±0.4	1.0±0.0	65-86	67-88	69-94	16-35

[a] Operation days. [b] Hydraulic loading rate (HLR), surface loading rate (SLR) and percentage removal efficiency.

Campaign I: low SLR (2.5 g BOD_5 m^{-2} d^{-1}), 2 first years
Campaign II: design conditions (<>5.0 g BOD_5 m^{-1} d^{-1}), 3rd year

RESULTS

Above-ground biomass production

CW unit	HSSF2		HSSF3		HSSF4		HSSF5	
Campaign	I	II	I	II	I	II	I	II
Total weight (kg m^{-2})	5.99	5.71	0.75	0.81	1.96	1.54	0.48	0.79
TS (%)	38.9	33.1	68.0	35.8	38.8	44.2	64.6	57.0
Dry weight (kg TS m^{-2})	2.33	1.89	0.51	0.29	0.76	0.68	0.31	0.45
VS (%ST)	95.7	95.2	96.1	96.6	96.1	97.1	100.0	97.8
Organic matter (kg VS m^{-2})	2.23	1.80	0.49	0.28	0.73	0.66	0.31	0.44
Biomass production rate (kg VS m^{-2} yr^{-1})	1.12	**1.80**	0.25	0.28	0.37	0.66	0.16	0.44
Biomass production rate (I/II)	0.62		**0.89**		0.56		0.36	

- ***Iris*** **was the quickest in stablishement**
- ***Juncus*** **reached the higher production**
- **Above-ground biomass production rates (VS) were in the same order of magnitude of organic solids accumulation rates**

RESULTS

Surface density of accumulated solids and main characteristics

	TS (kg m^{-2})	VS (%)	COD (g g^{-1} VS)	BOD_5 (g g^{-1} VS)	BOD_L (g g^{-1} VS)	ABD (g COD-CH_4 g^{-1} VS)
Probability (p) [a]						
C-I						
Units	0.084	0.501	0.368	0.560	0.810	0.347
I-O	0.163	**0.028**	**0.018**	0.519	0.786	**0.029**
C-II						
Units	0.866	0.021	0.036	0.046	0.163	0.174
I-O	0.145	**0.079**	0.053	0.305	**0.020**	**0.080**
Mean values						
C-I	2.16	7.9	1.53	0.128	0.57	0.078
C-II	4.29	10.9	1.77	0.219	0.61	0.054
p Units[a]	0.681	0.726	0.791	0.721	0.568	0.008
p I-II [a]	**0.002**	**0.086**	0.386	**0.032**	0.500	**0.012**

C-I: Campaign I, C-II: Campaign II. I: inlet zone. O: outlet zone. [a]ANOVA of two factors with only one data per group.

For most characteristics of accumulated solids:

- **Significant differences between near inlet and outlet zones, as well as between campaigns I and II**

RESULTS

Surface density of accumulated solids and main characteristics

	TS ($kg\ m^{-2}$)	VS (%)	COD ($g\ g^{-1}$ VS)	BOD_5 ($g\ g^{-1}$ VS)	BOD_L ($g\ g^{-1}$ VS)	ABD ($g\ COD\text{-}CH_4\ g^{-1}$ VS)
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- **No significant differences between units for TS density, VS density, COD/VS and BOD/VS**
- **ABDwas significantly higher in the *Juncus effusus* unit**

RESULTS

Surface density of accumulated solids and main characteristics

	TS (kg m^{-2})	VS (%)	COD (g g^{-1} VS)	BOD_5 (g g^{-1} VS)	BOD_L (g g^{-1} VS)	ABD (g COD-CH_4 g^{-1} VS)
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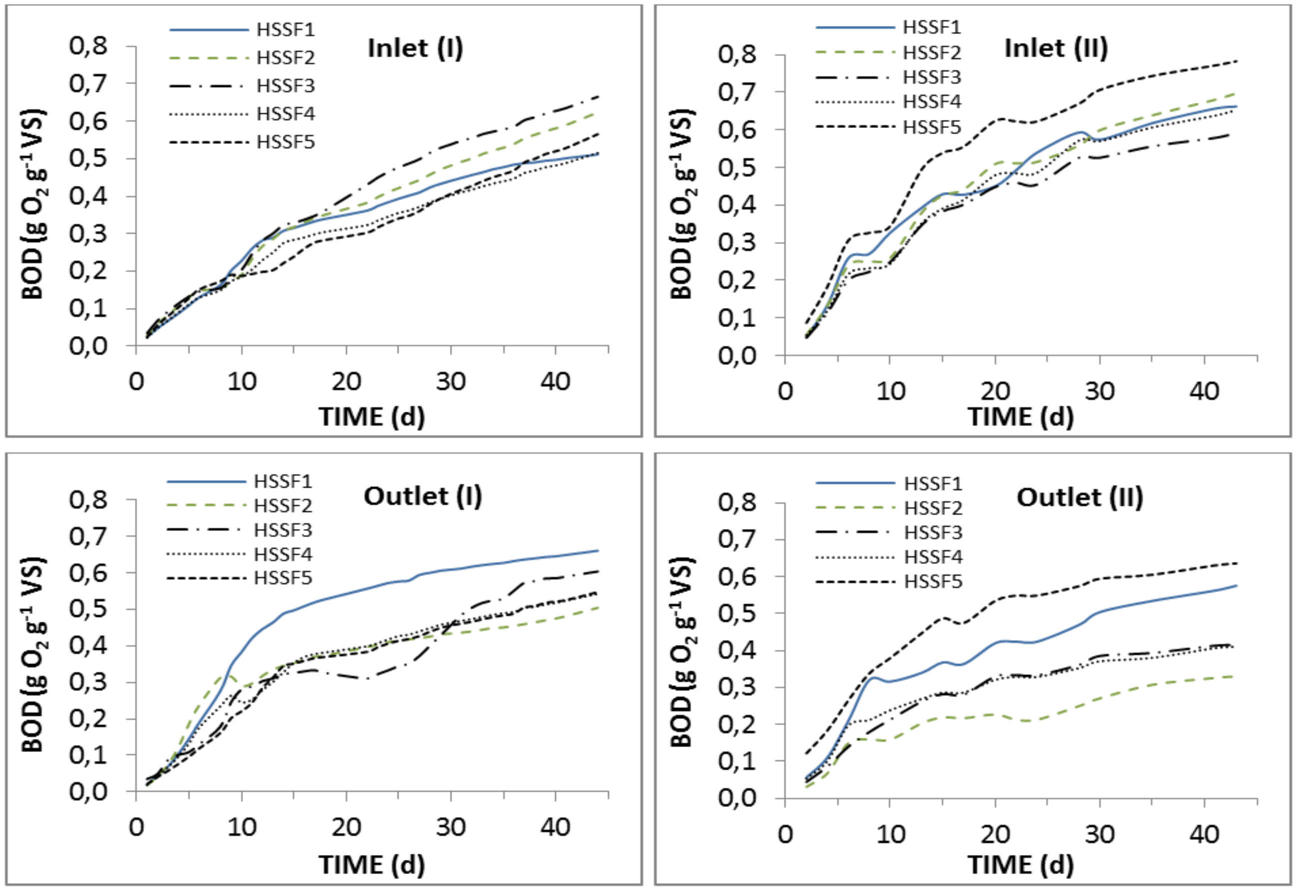
Solids accumulation rates:

- 1.5 kg TS m^{-2} yr^{-1} (from starting to C-I, SLR 2.5 g BOD_5 m^{-2} d)
- 2.5 kg TS m^{-2} yr^{-1} (from C-I to C-II, SLR 4.7 g BOD_5 m^{-2} d)

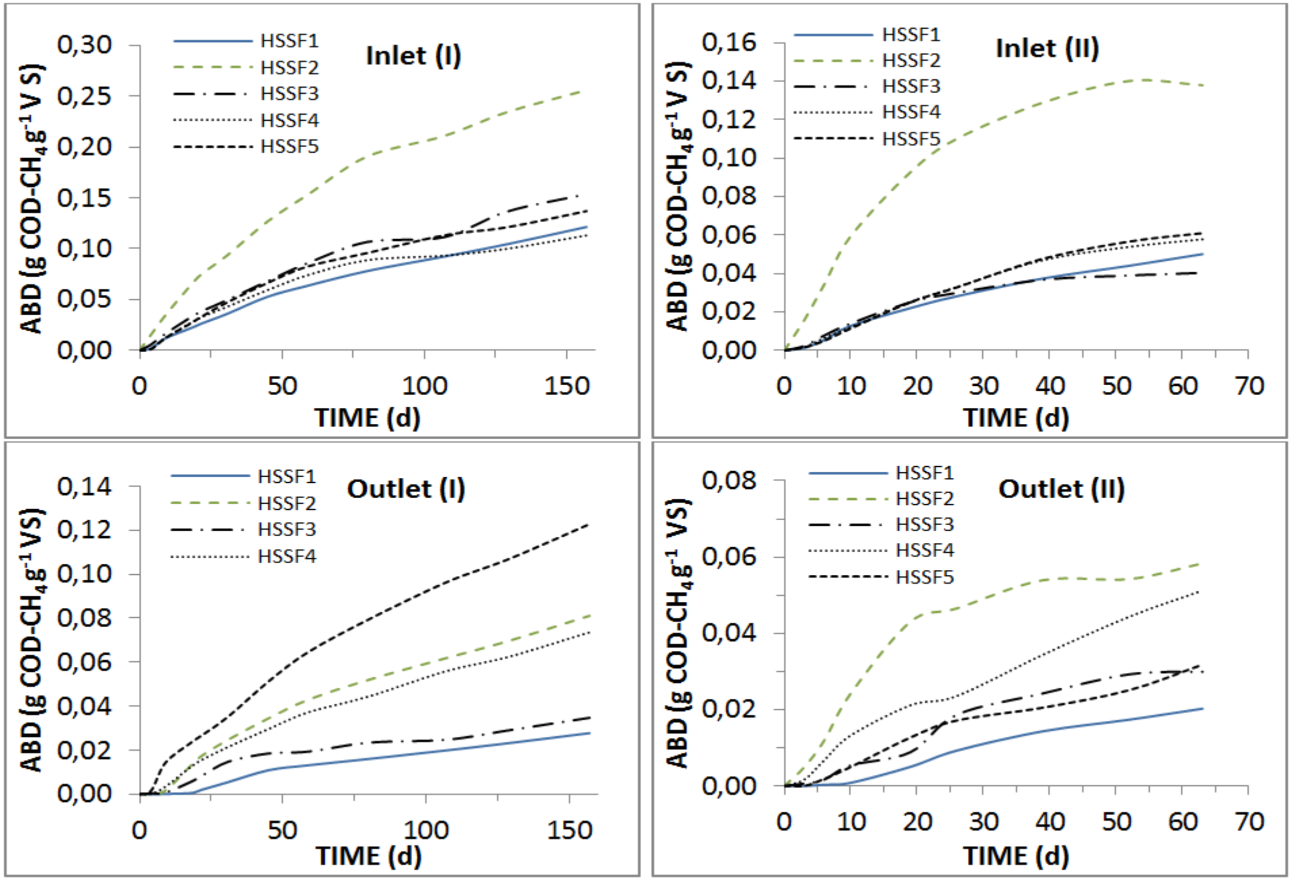
RESULTS



BOD curves: Time profiles of aerobic biodegradability (BOD curves) of accumulated solids in HSSF units at campaigns I and II.

➢ **Inflection point at about 14 days → Initial high rate period (R1)**

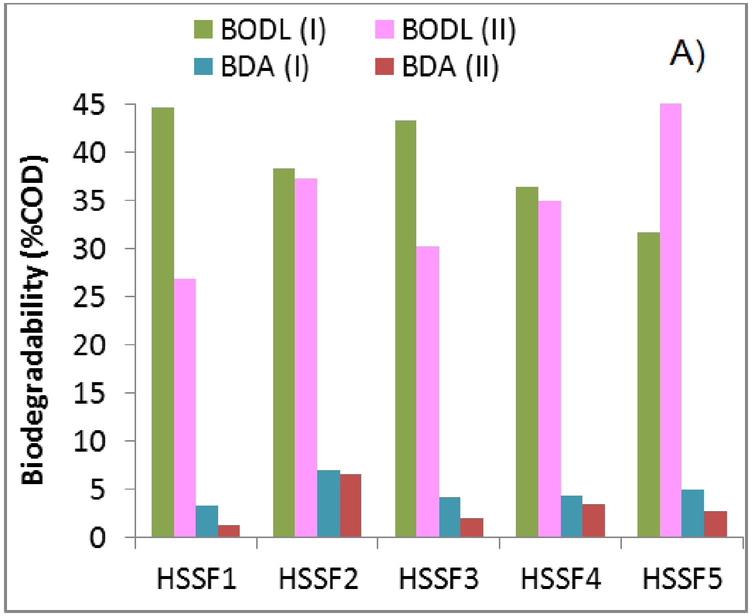
RESULTS

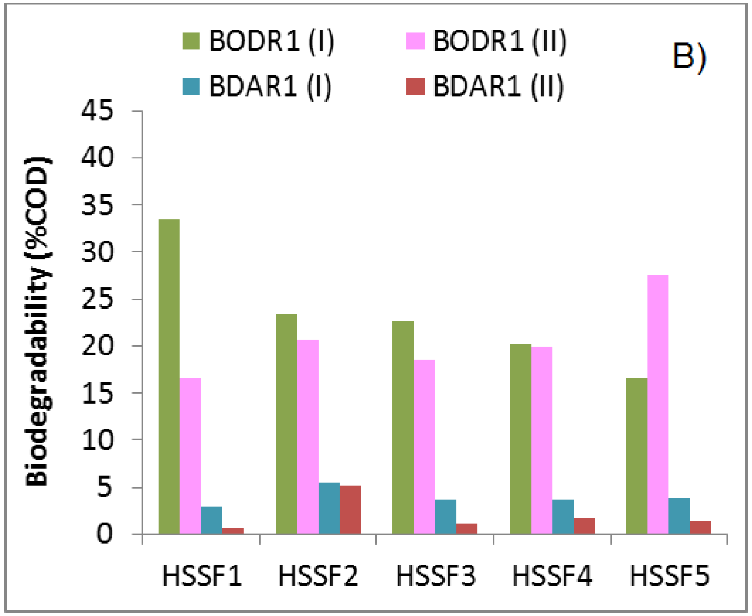


ABD curves: Time profiles of anaerobic biodegradability of accumulated solids.

Longer process, inflection point ranging from 20 to 60 days

RESULTS





Readily and total biodegradability:

A: total biodegradability obtained from BOD_L and final ABD values **~ 35%, ~ 4%**

B: readily biodegradability obtained from the initial R1 high rate period **~ 20%, ~ 3%**

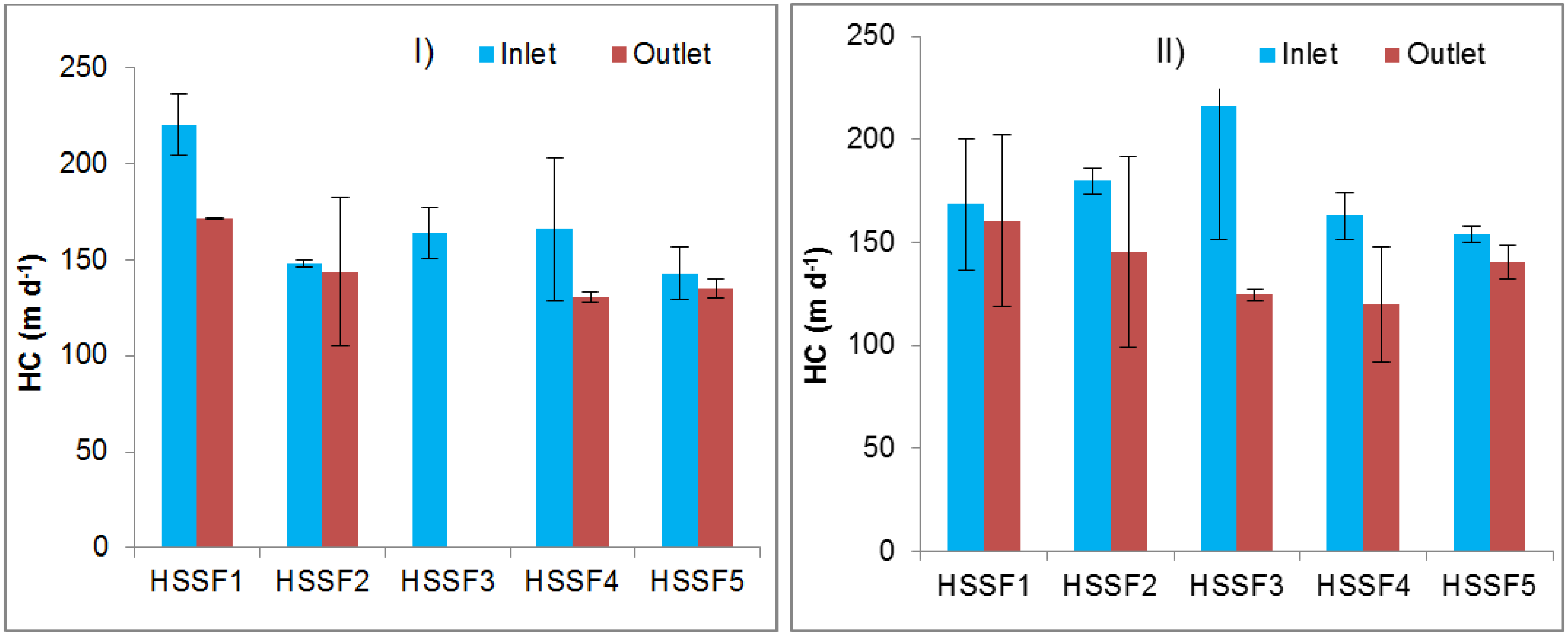
Equations for initial high rate (R1), readily biodegradability :

- **BOD-R1 (%COD) = $(BOD_{R1} \cdot t_{R1} / COD) \cdot 100$**
- **ABD-R1 (%COD) = $(ABD_{R1} \cdot t_{R1} / COD) \cdot 100$.**

(from slope of curves during R1)

Aerobic biodegradation rates were about one order of magnitude higher than anaerobic biodegradation rates

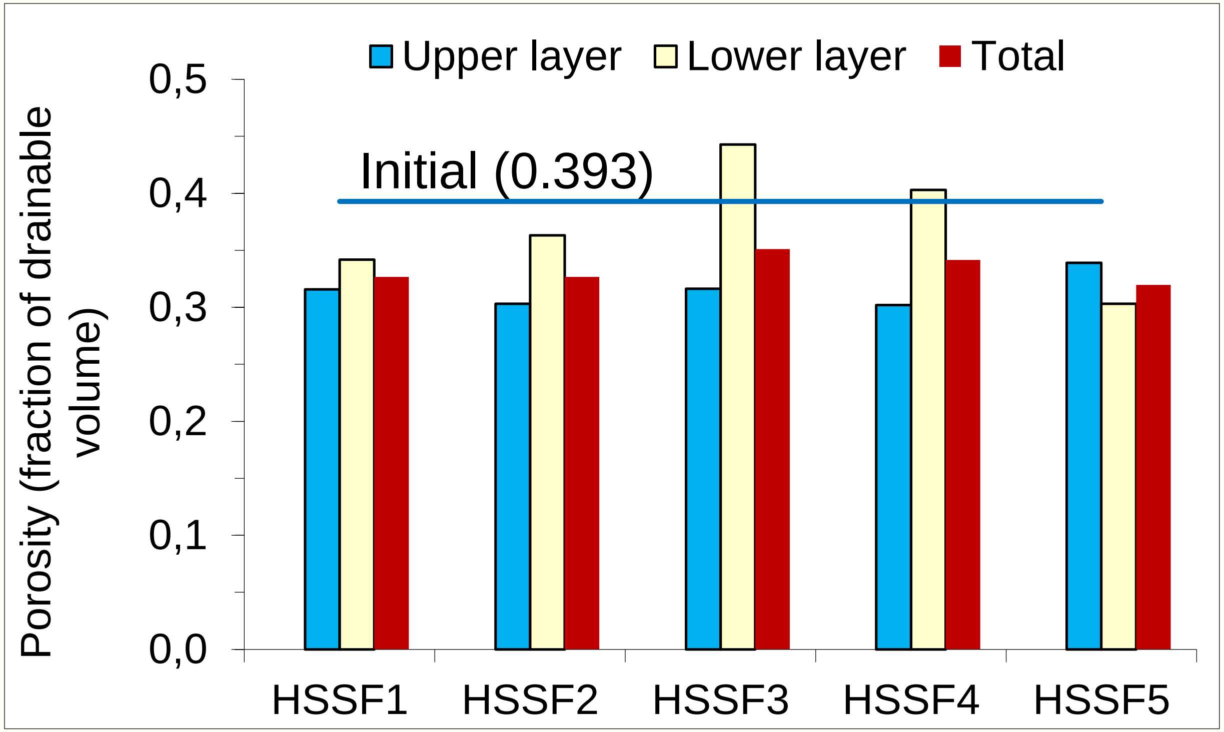
RESULTS



Hydraulic conductivity of gravel bed at campaigns I and II
(mean value obtained for the same transversal position, n=4, and standard deviation)

High HC but 16% lower in planted units than in the unplanted unit.

RESULTS



Drainable porosity of gravel bed: Upper layer: from 29 to 17 cm water table, Lower layer: from 17 cm to 10 cm water table

- **13-18% reduction of initial porosity**
- **Attributable to the accumulation of solids and its water holding capacity**

CONCLUSIONS

1. Limited differences in solids accumulation and solids characteristics among units planted with different species and even that unplanted (conditions: plant harvested).
2. However, significant differences were found between near inlet and outlet zones, as well as between campaigns I and II.
3. Harvesting can be an important factor in reducing organic solids accumulation in CWs.
4. Maximum surface aerobic biodegradation rates were about one order of magnitude higher than anaerobic biodegradation rates.
5. Promoting aerobic conditions in HSSF CWs can help in preventing clogging.
6. It was found a reduction of initial porosity of 13-18%, attributable to the accumulation of solids and its water holding capacity.
7. The hydraulic conductivity remained high, but 16% lower in planted units than in the unplanted unit.

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THANK FOR YOUR ATTENTION

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