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Performance of experimental horizontal subsurface flow constructed wetlands fed with dissolved or particulate organic matter

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ABSTRACT

In this study, the effect of the influent type of organic matter (dissolved or particulate) on the efficiency of two experimental horizontal subsurface flow constructed wetlands (SSF CWs) was investigated. The SSF CWs' surface area was 0.54 m^2 and the water depth was 0.3 m. They were monitored for a period of 9 months. One of the SSF CWs was fed with dissolved organic matter (glucose, assumed to be readily biodegradable), and the other with particulate organic matter (starch, assumed to be slowly biodegradable). The removal efficiency of the systems was tested at different hydraulic retention times (HRTs) in the presence or absence of sulphate. The removal efficiency of the COD was not different in the two systems, reaching eliminations of around 85% in the presence of sulphates and around 95% in their absence. Ammonia N removal was low in the two SSF CWs; the system fed with glucose generally had statistically significant higher removal (45%) than the one fed with starch (40%). Ammonia N removal was more affected by the HRT than by the presence or absence of sulphates. Hydraulic conductivity measurements showed that it was lower near the inlet of the SFF CW fed with glucose, probably connected to the fact that there was a more substantial development of the biofilm. The results of this study suggest that SSF CWs are not sensitive to the type of organic matter in the influents, whether it is readily (like glucose) or slowly (like starch) biodegradable, for the removal of COD.

1. Introduction

Horizontal subsurface flow constructed wetlands (SSF CWs) are low-cost treatment systems in which wastewater flows slowly across the gravel and the roots and rhizomes of the emergent planted vegetation. The removal of contaminants occurs as a result of complex physical, chemical and microbial interactions (Kadlec and Knight, 1996). The rates of these processes may vary in time and space, and depend on many factors such as the organic surface loading rate, the depth of the water and the availability of electron acceptors (García et al., 2004a; Aguirre et al., 2005).

Although SSF CWs have been used to treat a wide range of wastewaters, they are most commonly used to treat domestic and municipal wastewaters. One of the major objectives of these systems is the removal of the organic matter. Wastewaters contain complex mixtures of organic matter of different size and types, from dissolved to particulate, and from readily biodegradable to inert constituents (Kadlec, 2003; Levine et al., 1991). Long-term experience in conventional wastewater treat-

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ment systems has demonstrated that the size frequency distribution function of the organic matter is a key factor in determining the removal efficiency (Sophonsiri and Mongenroth, 2004). Particulate organic biodegradable substrates (as well as high-molecular-weight dissolved and colloidal constituents) must undergo cell external hydrolysis before they are available for biodegradation (Gujer et al., 1999). This hydrolysis process can be one of the most limiting steps during the removal of organic matter either under anaerobic, anoxic and aerobic conditions (Mino et al., 1995; Ubukata, 1997; Sanders et al., 2000).

There is currently no experimental information available on the comparative effect of particulate and dissolved substrates on the removal efficiency of SSF CWs. Several reports, nevertheless, have recently discussed in a theoretical manner the possible effect of particle size distribution. For example, Kadlec (2003) inferred the removal efficiency of different contaminants as a function of their size and also of their physico-chemical properties. Tchobanoglous (2003) pointed out the importance of organic matter size distribution as a design criterion, and reviewed pretreatment systems for reducing particulate substrates and therefore for modifying the size distribution function. Baptista et al. (2003) discussed the possible mechanisms for organic matter removal as a function of its size distribution function. In the present study we experimentally evaluated the removal efficiency of two identical experimental SSF CWs operated under the same conditions, but one fed with starch (as a slowly biodegradable particulate substrate) and the other with glucose (as a readily biodegradable dissolved substrate). The efficiency of the systems was tested using different hydraulic retention times (HRTs) as well as with the presence or absence of sulphate, which in previous studies has been observed to be an important electron acceptor in SSF CWs that treat municipal wastewaters with high sulphate content (Aguirre et al., 2005).

2. Material and methods

2.1. Experimental SSF CWs

SSF CWs were built using plastic containers (0.93 m long, 0.59 m wide and 0.52 m high) filled with wetted gravel extracted from a pilot SSF CW system located at Les Franqueses del Vallès, Barcelona, Spain. This pilot system started operating in 2001 (García et al., 2004a). The containers had a drainage pipe located on the bottom of one of their sides. The bottom was flat. Gravel depth was 0.35 m (the diameter at which 60% of the material passed through the sieve was $D_{60} = 3.5$ mm, the uniformity coefficient was $C_u = D_{60}/D_{10} = 1.7$ and the initial porosity was 40%) and the water level was maintained at 0.05 m under the gravel surface to give a water depth of 0.30 m. In April 2004, reed rhizomes (*Phragmites australis*) were planted in the experimental systems and stored in the Environmental Engineering Laboratory (Technical University of Catalonia, Barcelona) in order to avoid great temperature variations. In addition to environmental light, each experimental SSF CW was illuminated using 15 Grolux lamps that provided a total power of 540 W. Although plant cover was attained in 2 months, the reeds' stems were thinner and shorter than is usually observed in the field.

2.2. Influent preparation and experimental strategies

This study was carried out between April and December 2004 and four different experimental phases were established. Table 1 summarises the conditions under which the two SSF CWs were operated during these phases. One SSF CW was fed with an influent containing starch $(C_6H_{11}O_5)_n$ as slowly biodegradable organic matter and the other with an influent containing glucose ($C_6H_{12}O_6$) as readily biodegradable organic matter (Mino et al., 1995; Gujer et al., 1999). Throughout all the phases, the surface organic loading rate was maintained approximately constant and identical in both SSF CWs. Thus, 3.8 g of starch or 4.0 g of glucose were added on a daily basis to the water volume that was used as influent (10 or 20 L of tap or distilled water, depending on the phase). The weights of the starch and glucose were calculated in order to have the same theoretical influent COD concentration in both SSF CWs. For glucose, the amount was estimated using the stoichometric relation to the oxygen necessary for its oxidation. In the case of starch, a calibration curve between the starch mass and the COD was obtained and used. Major

Table 1 – Operational conditions used for both SSF CWs in the four different experimental phases

	Phase			
	I	II	III	IV
Date	May–June 2004	July–September 2004	September–November 2004	November–December 2004
Water used for influent	Tap	Tap	Distilled	Distilled
Flow (L/d)	20	10	10	20
Hydraulic retention time (d)	3	6	6	3
Influent COD concentration (mg/L)	150	300	300	150
Surface loading rate (g COD/m^2 d)	6	6	6	6
Influent NH_3 concentration (mg N/L)	13	26	26	13
Presence of SO_4^{2-}	Yes	Yes	No	No

One SSF CW was fed with starch, the other with glucose. The values of COD and NH_3 concentrations and surface loading rates are based on theoretical calculations.