INTEGRATED TREATMENT OF WASTEWATER, URBAN RUNOFF AND SLUDGE WITH CONSTRUCTED WETLANDS

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Abstract

In recent years constructed wetlands have proven their potential for separately treating wastewater, urban runoff and sludge. We have integrated these systems by developing a comprehensive design suitable for the sanitation of small communities. The aim of this research was to assess the performance of a combined treatment system based exclusively on constructed wetlands. For that purpose, the treatment efficiency of a combined full-scale wastewater treatment system located in Seville, Spain, was monitored. The system consisted of an imhoff tank followed by a vertical flow (317 m^2), a horizontal subsurface flow (229 m^2) and a free water surface flow (240 m^2) wetlands, connected in series. The sludge generated in an extended aeration activated sludge unit was disposed, after its thickening, onto another constructed wetland bed with the purpose of achieving its drying and mineralization. The hybrid system based on constructed wetlands proved capable of accomplishing a good treatment of a combined sewer effluent and the sludge produced in the process. The quality of the final treated wastewater fulfilled the requirements for its reuse in various environmental applications, such as irrigation of green areas non accessible to the public and silviculture. The occurrence of stormy periods did not jeopardize the correct functioning of the system, which was able to recover to usual levels after the rain event.

Keywords: constructed wetland; runoff; sludge; urban wastewater.

Introduction

Constructed wetlands (CWs) are natural treatment systems that have shown their potential for the treatment of wastewater, as well as the sludge produced in treatment processes. Oftentimes the wastewater is collected in a combined sewer system together with the runoff from a rain event. We have developed a comprehensive approach aimed at combining different types of constructed wetlands for an integrated sanitation of small communities.

The scope of this study was to assess the performance of an integrated approach for the treatment of wastewater, sludge and urban runoff based exclusively on CWs. A pilot-scale treatment system consisting of different types of wetlands was put into operation and monitored over a period of about 1.5 years. The goal of the treatment system was to remove organic matter, nutrients and fecal indicators of the wastewater so as to provide effluents suitable for various water reuse applications, and additionally to treat thickened activated sludge with similar characteristics to that produced in the imhoff tank. Moreover, the influence of some pulses of high flow at the beginning of a rain event or 'first flush' events over the treatment performance of the system was examined.

Methods

The treatment system was part of a larger pilot-scale treatment plant that received the wastewater from 2000 P.E. from the municipality of Carrión de los Céspedes, Seville. In particular, the CW-based treatment line consisted of an imhoff tank as a primary treatment, followed by three different constructed wetland configurations. The primary effluent flowed into a vertical flow constructed wetland (VF) of 317 m^2 of surface area, a 229 m^2 horizontal subsurface flow wetland (HSSF) and finally into a 240 m^2 free-water surface wetland (FWS). They all were planted with *Phragmites australis* and received an average flow of about 14 $m^3\ d^{-1}$. The organic loading rate entering the VF wetland was around 9.6 g $BOD_5\ m^{-2}\ d^{-1}$. Furthermore, the waste sludge produced in an extended aeration activated sludge unit was thickened before disposal onto a sludge treatment wetland (19.6 m^2) in order to achieve its drying and mineralization. The sludge bed was fed manually once per month, with a loading pattern of about 42 kg total solids (TS) $m^{-2}\ year^{-1}$. This sludge had similar characteristics to those found in the one produced in the imhoff tank.

The effluent of the different treatment units of the experimental plant were monitored once a week from July 2009 up to date, in terms of organic matter (BOD_5, COD), total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP). Furthermore, the influence of first flush events during periods of high rainfall over the performance of the system was examined in order to assess the buffer capacity of the wetlands and its recovery back into a normal functioning.

Results and discussion

The results for TSS (Fig. 1) show a high degree of removal (80%) within the imhoff tank, with the consequent removal of 92% of the remaining solids in the wetlands, up to a final average value of 8 mg L^{-1}. On the other hand, values for COD and BOD_5 show that most of the removal of the organic matter took place in the VF wetland (85-95%), being the average value of the final effluent for BOD $_5$ of 8 mg L^{-1}

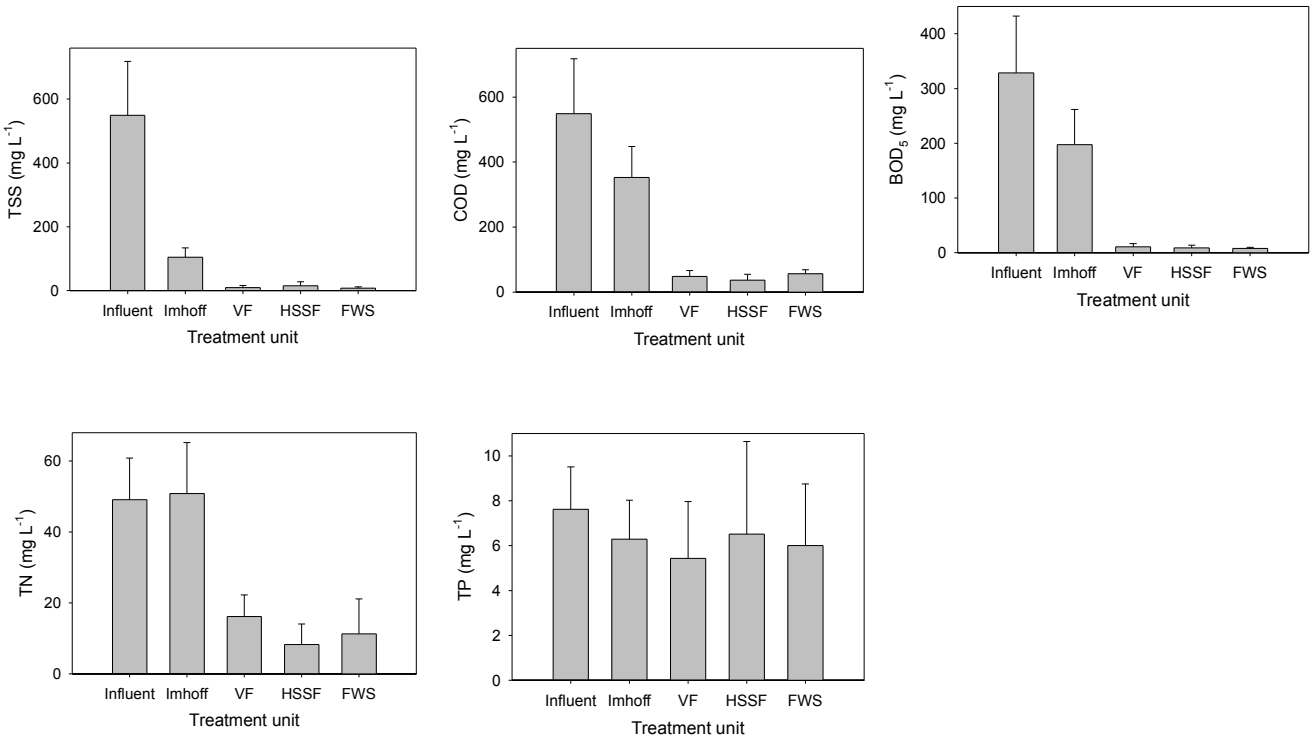

Figure 1. Water quality characteristics at the effluent of the different units of the treatment plant.

In regards to the nutrients contained in the wastewater, it is important to note the substantial degree of removal of TN within the VF wetland (68%), where both processes of nitrification and denitrification presumably take place. This could happen due to the existence of various microenvironments within the wetland that would sustain both oxidized and reduced conditions (Cooper et al, 1996). Nonetheless, the removal of TP is in any case limited, with a total removal rate of 21% of the incoming phosphorus.

The final effluent is collected in a water tank with a capacity of 20 m^3, and its quality fulfills the guidelines for some water reuse applications, such as the recharge of aquifers by percolation through the ground, irrigation of green areas non accessible to the public and silviculture (RD 1620/2007).

The rainfall that took place for about one week before the selected sampling days ranged from 41-120 mm and the flow of the wetlands raised up to 37 m^3 d^{-1}.The results for these are summarized in Table 1.

Table 1. Average water quality characteristics under first flush events at the effluent of the different units of the treatment plant.

	Influent	Imhoff tank	VF	HSSF	FWS
TSS (mg L^{-1})	3814.0 ± 3104.9	16.8 ± 8.5	22.3 ± 9.4	1631.8 ± 1158.4	2147.3 ± 3700.2
COD (mg L^{-1})	---	48.8 ± 17.4	85.5 ± 38.7	61.5 ± 23.3	38.5 ± 3.5
BOD_5 (mg L^{-1})	---	11.6 ± 0.9	22.8 ± 11.5	12.5 ± 0.7	12.0 ± 0.0
TN (mg L^{-1})	---	22.4 ± 9.5	31.5 ± 15.4	42.5 ± 18.3	30.9 ± 30.8
TP (mg L^{-1})	---	1.0 ± 0.08	1.7 ± 0.63	1.8 ± 0.08	0.9 ± 0.0

As it can be observed, the amount of TSS in the influent wastewater is extremely high, due to runoff sediment transport and resuspension of the material previously deposited in the sewer system.These solids seemed to be of mineral origin, as we can observe by the low values of COD and BOD_5 entering the system.The level of entrapment of these solids in the Imhoff tank is remarkable. However, a steady increase of their concentration in the HSSF and FWS took place through the drag of the solids retained in the gravel bed of the wetlands at high hydraulic loading rates (dry period = 0.07 ± 0.02 $m^3 m^{-2} d^{-1}$; rainy period = 0.12 ± 0.05 $m^3 m^{-2} d^{-1}$). As it has been mentioned, the influent concentration of both the organic matter and nutrients is significantly lower than in the normal period due to the dilution of the wastewater. Therefore, the percentage of removal for COD, BOD_5 and TP are lower than those found in the normal period. However, the concentrations of TN appear to increase in the HSSF wetland, which could be owed to its drag or resuspension in this system under this flow conditions. However, those events do not significantly affect the efficiency of the system, showing a complete recovery of its performance after the rain events.

Results for the sludge quality are being processed at the moment and are to be presented in the conference. Furthermore, a small-scale treatment plant with the same wetland configuration has been constructed in Barcelona in order to carry out assays of simulation of rainfall events, and the results will also be shown further on.

Conclusions

The hybrid system based on constructed wetlands appears as an integrated approach capable of accomplishing a good treatment of a combined sewer effluent and the sludge produced in the process. The quality of the final treated wastewater fulfills the requirements for its reuse in various environmental applications, such as irrigation of green areas non accessible to the public and silviculture. The occurrence of stormy periods does not jeopardize the correct functioning of the system, which is able to recover to usual levels after the rain event.

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