Design and first results of a subsurface vertical flow constructed wetland for individual sanitation in Galicia

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Abstract

Galicia's population is characterized by its high dispersion, which means that the number of households without sewage treatment is very high compared to other Spanish regions. Due to this fact, there is great need to examine the possible use of certain types of low cost sanitation as an alternative to reduce the problem. A constructed wetland has been built to treat the effluent coming from a household. The treatment system is composed by a septic tank of 500 dm3 and three subsurface vertical flow constructed wetlands working in parallel of 3,3 m2 each. The main objective of this study is to increase the knowledge regarding wetlands, particularly those of vertical flow, and the characterization of its operating parameters for the implementation in households or small communities in Galicia. The results during the start up period indicate an average removal efficiencies of 48 % total suspended solids (TSS), 67 % chemical oxygen demand, 65 % biological oxygen demand (BOD_5), 34 % total nitrogen and 45 % total phosphorus for overall system. Subsurface vertical flow constructed wetlands are therefore considered a good alternative for individual sanitation in Galicia.

Introduction

The population in Galicia is characterized by its high dispersion. About 21% of the population either lack sanitation system or only have a septic tank with poor results and yields. Therefore, domestic and agricultural wastewater is usually discharged into surrounding streams and rivers causing water pollution (Galicia´s Sanitation Plan, 2000-2015).

In small communities there are two possibilities regarding wastewater treatment; connecting them to an urban group or considering them as isolated individual groups. The latter is the most favourable option because conventional wastewater treatment systems are a complicated and expensive technology that is unsuitable for such communities.

Constructed wetlands have proved to be highly efficient wastewater treatment systems. It is a low cost technology, it requires low maintenance, it has a null energetic cost and it generates a minimum amout of sludge. Moreover it is good for the ecosystem since the plants can be a habitat for different kinds of animals and birds. These characteristics make constructed wetlands a good alternative to conventional systems for the sanitation of small communities (García and Corzo, 2006).

Although researches on constructed wetlands are ongoing at many places around the world, a few studies of these systems have been carried out in Galicia (Puigagut, 2007). There are three main basic types of wetland treatment systems based on their water flow; natural wetlands, surface flow and subsurface-flow constructed wetland. Wastewater flows by gravity, vertically or horizontally, through the bed matrix.

The earliest forms of subsurface vertical flow systems were those of Seidel in Germany in the 1960s (Vymazal, 2009). Interest in this particular process seemed to wane but it has been revived in the last decade because of the need to produce beds which nitrify (Vymazal and Kröpfelová, 2008). These systems comprise a flat bed of graded gravel topped with sand planted with macrophytes. The size fraction of gravel is larger in the bottom layer and smaller in the top layer. Vertical flow constructed wetlands are fed intermittently with a large batch thus flooding the surface. Wastewater then gradually percolates down through the bed and is collected by a drainage network at the base. This dosing pace leads to good oxygen transfer and hence the ability to nitrify. Many of the vertical-flow systems are staged systems with parallel and series bed. Sometimes there are parallel beds which are fed in rotation for 1 to 2 days and then rested for periods of 3 to 6 days (Prochaska et al., 2007). The main objective of this study is to increase the knowledge regarding wetlands, particularly those of vertical flow, and the characterization of its operating parameters for the implementation in households or small communities in Galicia.

Methods

The experimental plant is located in a household in Teo (A Coruña, Spain). The plant was constructed in March 2009. The data considered in this study ranges from August09 to January 2010. The scheme of the plant is showed in Figure 1. The septic tank has a volume of 500 dm3 and was fed with raw domestic wastewater from the house. The effluent of the septic tank goes into the constructed wetlands system, consisting of three wetlands (Polyester tanks of 2 m^3 and 3,3 m^2) working in parallel with intermittent load (four loadings a day in average). The experimental plant has been operated automatically.

The composition of substrates for all reactors is: 10 cm layer of sand main (∅ 2 mm), 35 cm layer of gravel (∅ 4-8 mm), 15 cm layer of gravel (∅ 12-16 mm) and 15 cm drainage layer gravel (30-60 mm).The distribution system consisted of three pipes with holes of 20 mm spread over the surface of the wetland. Each system has 26 emitters.

Species of emergent macrophytes selected for the system are mixed *Typha sp.* and *Iris pseudacorus* (VFCW 1), *Typha sp.* (VFCW 2) and *Iris pseudacorus* (VFCW 3).

The organic load applied to the three beds was 24 $gDBO_5/m^2/d$, which corresponds to a specific area demand of 2,5 m^2 per person (when considering a specific pollutant load for 60 $gDBO_5/d$ per person).

A total of 844 feeding pulses were applied in the overall system and 11 cycles were sampled. During each cycle, integrated water samples were collected daily. The inflow is taken after septic tank, and the outflow in each reactor. Analysis of total and volatile suspended solids (TSS, VSS), total chemical oxygen demand (TCOD), biological oxygen demand (BOD_5), nitrogen (TN, NH_4-N, NO_2-N and NO_3-N), and total phosphorus (TP) were carried out in the laboratory, while temperature and pH were determined *in situ*. Except for temperature and flow, all parameters were determined by methods in accordance with *Standard Methods* (1995).

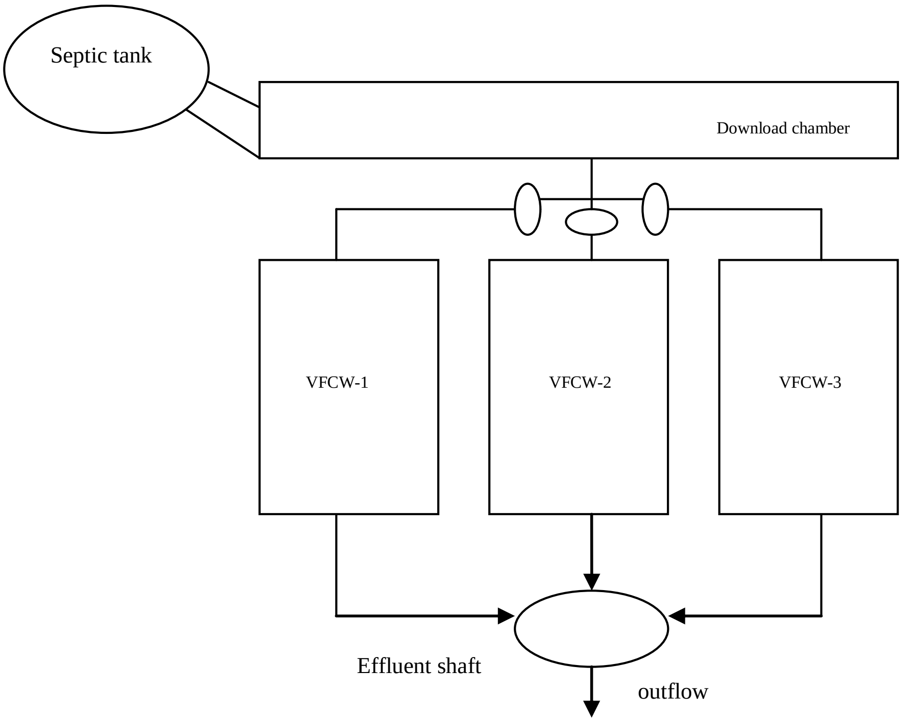

Figure 1. Schematic layout of the experimental plant in Teo (A Coruña, Spain).

Results and Discussion

Table 1 summarizes the characteristics of the wastewater from this household, pre-treated in a septic tank. It presented a strong organic load because in small communities lower endowment results in less dilution and shorter reaction of the pollutants before treatment (Metcalf and Eddy, 2003). Constructed wetlands are stable systems against variations of organic and hydraulic loads, and therefore constitute a good alternative for the wastewater treatment of small communities.

Figure 2 shows the evolution of the concentration in TSS, TCOD, BOD5 in VFCW systems during the start up period. The operating characteristics during this period were one day of application and two days of dry period, with an hydraulic load of 8,3 mm/d. In such conditions, the average percentage of removal was 55 %, 46 % and 44 % in total suspended solids; 69 %, 62% and 70 % in total chemical oxygen demand; and 68 %, 62 % and 67 %, in biological oxygen demand, for VFCW-1, VFCW-2, and VFCW 3, respectively. Removal rates for suspended solids and organic matter were lower than other studies where the surface area should be > 3 m^2/PE (Brix and Arias, 2005)

The strong variations found in concentration of the system could be due to a bad distribution of influent, to the temperature of the system, low representativeness of samples collected, to a high concentration of influent or most likely due to the fact that the system is in the start up period. By the end of the operating period it has been observed a stabilization of such behaviour. This aspect should be revised in the near future.

Table 1. Characteristics of wastewater from the household object of this study.

	pH	TSS	VSS	TCOD	BOD5	NH4-N	NO3-N	TN	TP
June 09	7,69	116	107	654	207	146,0	0,90	174,0	14,9
July 09	7,93	123	117	539	182	141,1	0,90	149,3	14,4
August 09	8,19	146	134	601	200	222,3	0,90	234,1	17,7
September 09	7,78	121	111	518	165	193,6	1,03	197,0	18,2
October 09	7,34	98	97	438	140	91,3	1,20	102,0	10,1
November 09	8,03	263	263	943	207	229,7	0,90	248,0	26,1
December 09	8,54	132	128	513	170	141,8	2,39	156,0	15,4
January 10	7,47	129	127	527	150	111,3	0,90	120,0	9,5
Average	7,87	141	136	592	178	159,6	1,14	172,5	15,8
Maximum	8,54	263	263	943	207	229,7	2,39	248	26,1
Minimum	7,34	98	97	438	140	91,3	0,9	102	9,5

Concentration in mg/L, except pH.

Concentrations and removal efficiencies of nitrogen and phosphorus compounds were 34 %, 32,3 % and 36,1 % of total nitrogen; 45,8 %, 40,3 % and 62,6 % of ammonia; 48,3 %, 47,3 % and 40,2 % of total phosphorus for VFCW-1, VFCW-2 and VFCW-3, respectively. The removal rates of nitrogen are similar to those shown in the literature for these systems, but removal phosphorus is higher because our system is in start up, and material granular are not clogging (Barros et al., 2008; Brix and Arias, 2005).

During operation time, various problems were observed related to design and performance of the system. Among those, low representativeness of samples collected, bad distribution of influent, low hydraulic retention time and hydraulic stress of water plants due to intermittent flow. In order to resolve this problem, work is being done to control automatically the discharged wastewater.

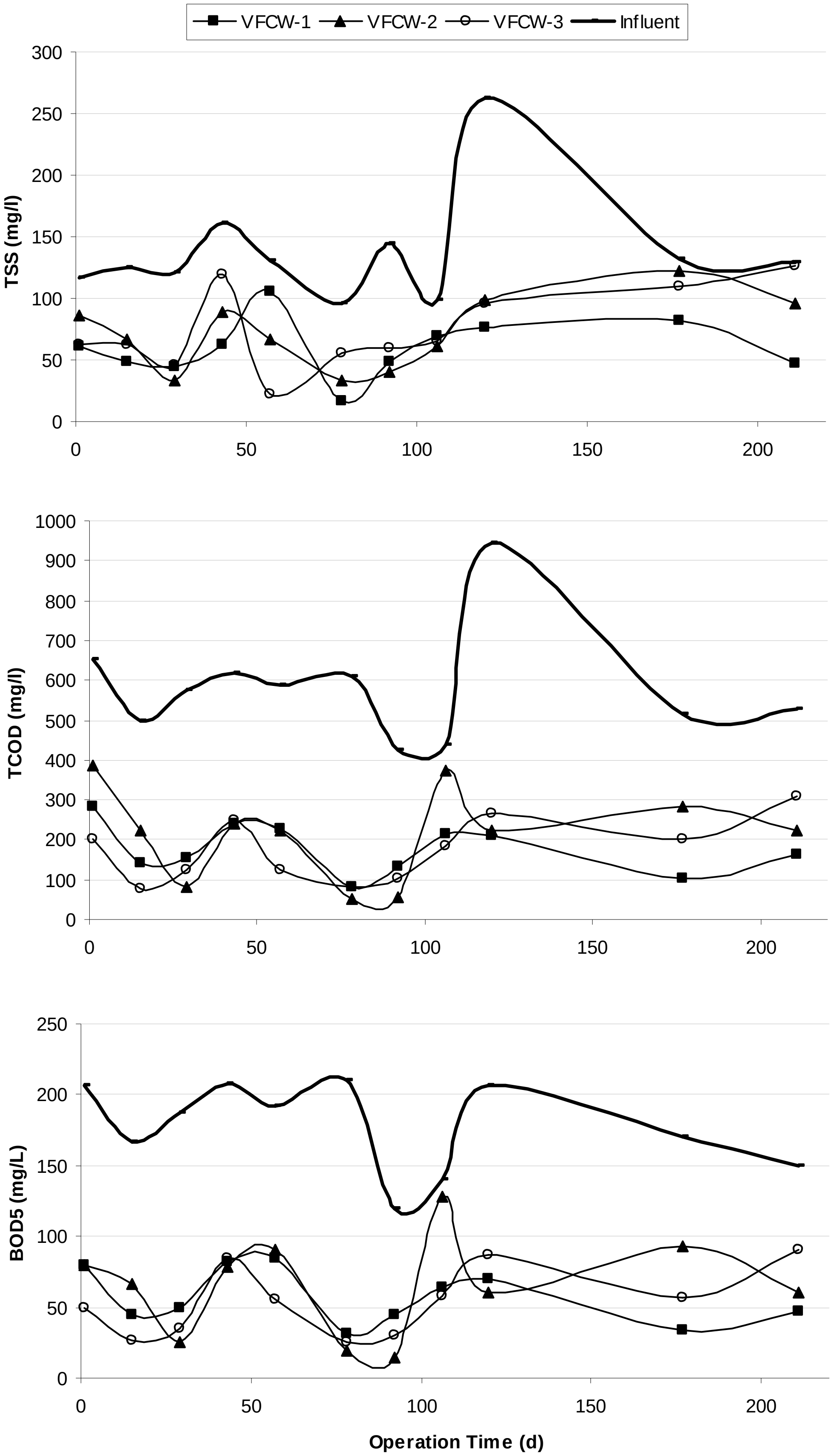

Figure 2. Evolution of the concentration of total suspended solids, total chemical oxygen demand and biological oxygen demand for overall system.

Conclusions

Despite the fact that the wetland system used was still in the start up period, the treatment system based in a septic tank and constructed wetlands is capable of improving the quality of the effluent. The average removal efficiencies for the whole system were of 48 % for total suspended solids (TSS), 67 % for chemical oxygen demand, 65 % for biological oxygen demand (BOD_5), 34 % for total nitrogen and 45 % for total phosphorus.

This treatment system can be used particularly in small communities or households because of its simplicity and reduced costs involved.

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