Modern Environmental Science and Engineering (ISSN 2333-2581)
March 2018, Volume 4, No. 3, pp. 258-262
Doi: 10.15341/mese(2333-2581)/03.04.2018/009
Academic Star Publishing Company, 2018
www.academicstar.us

Domestic Wastewater Treatment by Using A Two Stages Subsurface Vertical Flow Constructed Wetland: Removal Efficiency

Irleth S. Segura Estrada, and Sandra Vázquez Villanueva
Mexican Institute of Water Technology, México

Abstract: Constructed wetlands are a sustainable way for the treatment and reuse wastewater; this is because of their contaminant's high removal efficiency, easy construction, low cost of operation and maintenance compared with conventional systems for wastewater treatment. Constructed wetlands have been classified accord to their flow in surface flow constructed wetlands and subsurface flow constructed wetlands; these last are classified in vertical and horizontal due the water flow inside the system. The vertical constructed wetlands can work with a superior organic mass than horizontal constructed wetlands in a less area with the same flow to treat. This research has been focus on determine the removal of Biochemical Oxygen Demand and fecal coliforms from a domestic wastewater by using a two stages subsurface vertical flow constructed wetland which is planted with *Scirpus ssp* (tule); and its´s fluctuation stability in the input concentration, obtaining as a result a global removal of fecal coliforms of 99.99% (4.81 logarithmic units), a Biochemical Oxygen Demand removal of 94.46% and a constant removal even when it was a variation in the input concentration of these contaminants.

Key words: constructed wetland, domestic wastewater, fecal coliforms, organic mass

1. Introduction

Constructed wetlands (CW) has been defined as engineering systems, designed and constructed to use the natural functions of the wetlands, vegetation, ground and microbial population for the wastewater treatment, where each one of these functions occur in a more controlled and efficient way [1-3]. Their use has been principally focus on wastewater treatment and its´s reuse in developing cities, in which the poor soil conditions predominate, high phreatic level, prohibition of the discharge of waste water in areas of adsorption; As well as cities that do not have sufficient resources to implement costly technologies [1, 4, 5]. In this last point the use of a CW is a high viable alternative due to the Low energy and maintenance costs compared to conventional technologies; also with zero environmental impact and low waste production [6, 7].

The importance and significance of these systems is that they are more economical and provide benefits from reuse, since they are very efficient in the removal of organic matter, suspended solids, metals, excess nutrients (e.g., nitrogen, phosphorus, etc.) and pathogenic organisms [6, 8, 9]. Additionally the CW has presented economic and operational advantages during operation.

The removal of contaminants is done by mechanisms that have place between the vegetation, ground and microorganisms [10].

On the other hand, the CW have been classified in wetlands of surface flow (SFCW) and subsurface (SSFCW), these last are classified according to the

Corresponding author: Irleth S. Segura Estrada, Master of Science in Water; research areas/interests: alternate systems for the supply of water, drinking water, residual level housing and community water treatment. E-mail: irleth_segura@tlaloc.imta.

movement of water in horizontal (SSHFCW) and vertical (SSVFCW). The SSVFCW can operate with loads exceeding the s SSHFCW, occupying less space to treat the same flow rate which represents an advantage over others [9].

The aim of this was focus on determining the Biochemical Demand of Oxygen (BOD_5) and a residual water fecal coliform removal household type by means of a two-stage SSVFCW which is planted with vegetation type *Scirpus spp* (tule); and its stability in terms of fluctuations in the input concentration.

2. Materials and Methods

2.1 Constructed Wetland Description

This study has been made in 8.5 weeks in an experimental physical model of a two-stage SSVFCW in the Mexican Institute of Water Technology (IMTA), it has an effective total area for treatment of 5 m^2 (2.5 m^2 each stage) and a time of hydraulic retention (THR) of 7 days in the system (Table 1). The bed is divided in 3 layers of stone material with a height of 30, 20 and 20 cm (ascending), and material diameters of 20, 5 and 2 mm respectively [9]. The vegetation in this system was planted with *Scirpus spp*. (tule).

The two cells that forms the system has a network of polyvinylchloride (PVC) piping for the distribution of the residual water and a PVC pipe grooved to the bottom of the wetland for the collection of water (Table 2). The wetland is located under a roof of polycarbonate in order to avoid influence of variables by precipitation.

In addition, the system has 3 PVC pipes 2" diameter for the aeration of the substrate in each one of the cells. These tubes are 0.003 m thick grooves to effect the transfer of oxygen to the inside of the system (Fig. 1).

Table 1 Dimensions of the stage.

Dimensions (m)	
Lenght	2.79
Width	0.90
Deep	0.70

Table 2 Characteristics of distribution and collection pipes.

Characteristic	Distribution system	Collection system
Kind of pipe	PVC	PVC
Pipe diameter	2”	2”
Number of rows	3	1
Type of perforation	holes	grooves
Number of perforations	27	7
Length of perforation	-	0.05 m
Thickness of each perforation	0.003 m	0.003 m

Fig. 1 Distribution systems and aeration pipes.

2.1.1 Operation

The system was powered with domestic wastewater entering the treatment plant of the IMTA, which comes mainly from the health services of the different buildings of the institute, dining room and laboratories. Residual water has a BOD_5 average of 142 mg/L and 1.8×10^4 MPN/100 mL fecal coliform (FC); this is powered by 2 pulses per day (75 L each pulse) which are controlled through a system of valves that operate manually.

2.1.2 Efficiency of the Constructed Wetland

The FC during the experimentation of our work was determined by the method of simultaneous determination of total and fecal coliform using the technique of substrate chromogenic specific (Colilert) (Fig. 2), while to the BOD_5 was determined by the norm NMX-AA-028-SCFI-200. Known values proceeded to determine the efficiency of removal of these parameters in the two stages and was subsequently performed a linear regression with previously transformed data [log (x+1)] to determine the stability of the system by fluctuations of the load of pollutants.

3. Results and Discussions

The presence and removal of BOD_5 and FC are monitoring for 8.5 weeks after the stabilization of the system. No significant differences in the number of FC with respect to different sampling points, registering a gradual reduction in the point of sampling next to the output were. The system showed an efficient removal of FC 99.99% (4.81 logarithmic units) and BOD_5 a 94.46% (Table 3). These results coincide with those reported by Arias et al. (2003) [11] in has two stages, which recorded a removal of indicator bacteria between 99.5-99.9%, and by Li et al. (2012) [12] in its work related to sand filters, which recorded values of removal of FC of 99.9%.

Contrary to the proceeds by Song et al. (2006) [13] who reported percentages less removal than those obtained in our study, since they recorded a removal of FC of 99.6%.

Fig. 2 Technique of substrate chromogenic specific.

Table 3 Removal of FC and BOD_5 for stage.

Parameter	Stage 1			Stage 2			System complete
	Inlet flow	Flow rate	Removal (%)	Inlet flow	Flow rate	Removal (%)	Removal (%)
FC (NMP/100 mL)	1.50×10^6	2.12×10^2	99.94	2.12×10^2	9.38×10^0	94.75	99.99
BOD_5 (mg/l)	151.3	19.65	86.58	19.65	8.1	58.72	94.46

On the other hand, regarding the BOD_5 results are similar to those obtained in this work (94.46%) (Fig. 3), for example Langergraber et al. (2014) [14] obtained a percentage of 95% in vertical wetlands in two stages and Jong *et al*. (2016) obtained values of 92-96%.

During the operation of the SSVFCW were presented different concentrations of FC, which ranged from 3.38×10^5 - 3.89×10^7 MPN/100 mL and BOD_5 of 150-250 mg/L; however the system was kept in an average percentage of removal from the order of 99.99% for FC and a 94.46% for the BOD_5. These results corroborate cited by several authors [9, 15, 16] that assume that the CW are able to withstand fluctuations in loading of contaminants.

To corroborate this information a linear regression was made in which you can see that the data between the concentration of FC and reduction of logarithmic units follow a pattern similar to the linear with a value (R^2) close to 1 (0.90), which indicates that there is a high correlation coefficient between the concentration of input and the reduction of FC log units throughout the system (Fig. 4); This data is similar to that obtained by Molleda (2011), whose correlation coefficient R^2 = 0.99, was between the burden of FC and its rate of removal in a SSVFCW of urban and livestock waste water treatment with high concentrations of pathogens.

On the other hand, the results obtained regarding the BOD_5, shows a linearity with a coefficient of R^2 = 0.87 (Fig. 5), is not ideal but it is an acceptable result; being this coefficient less than introducing Molleda (2011)

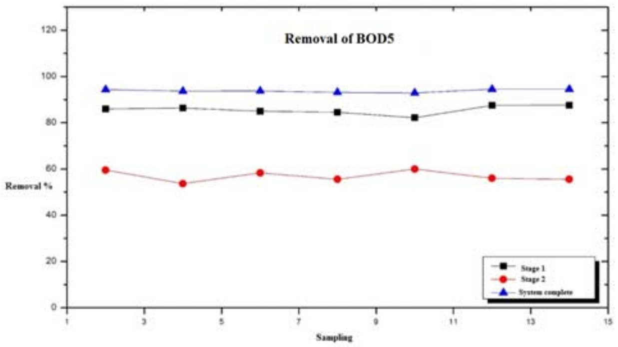

Fig. 3 Removal of BOD_5.

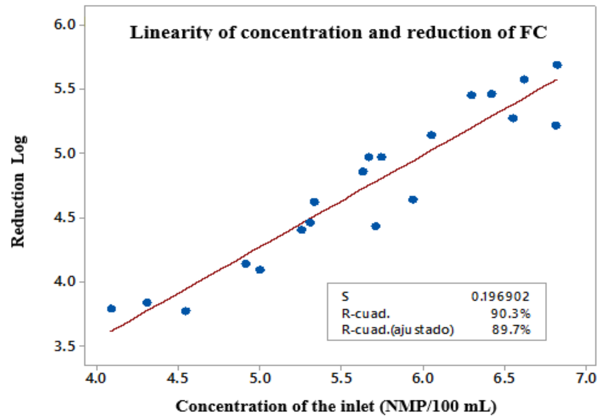

Fig. 4 Linearity of concentration and reduction of FC.

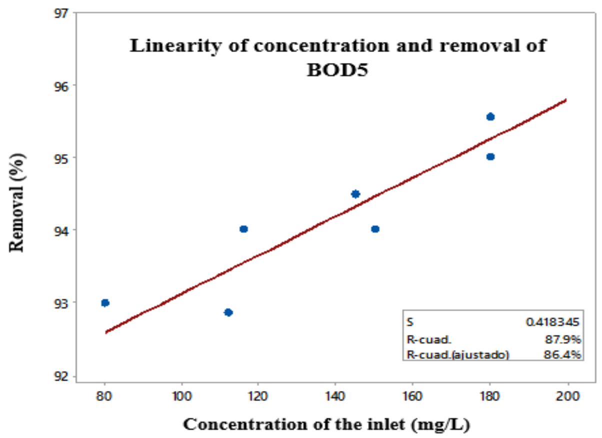

Fig. 5 Linearity of concentration and removal of BOD_5.

[16], between the load to the wetland and its elimination rate (R^2 = 0.98).

4. Conclusions

Indicator bacteria (FC) are effectively reduced by a SSVFCW reaching removals of 99.99%, i.e., in the order of 4.8 logarithmic units (MPN/100 mL); and regarding the BOD_5 removal average of 94.46% values are reached. These results are lower than those recorded in similar wetlands of horizontal type with HRT.

The system is not destabilized in terms of FC and BOD_5 removal by fluctuations in concentration of input, which corroborates that this type of wetlands can withstand pollutants concentration peaks without affecting its efficiency.

The removal of indicator bacteria and BOD_5 in this paper was conducted mainly in stage 1, so it is recommended to do a deeper analysis in terms of the size of such systems.

Organic loading rates analyzed in the present work are low compared with rates that use systems on a large scale, so it is still studying whether the concentration of output reaches similar values of clearance when the organic rate increases.

References

[1] A. Karathanasis, C. Potter and M. Coyne, Vegetation effects bacteria, BOD, and suspended solid removal in constructed wetlands treating domestic wastewater, *Ecological Engineering* 20 (2003) (2) 157-166, doi: 10.1016/S0925-8574(03)00011-9.

[2] J. Vymazal, Constructed wetlands for wastewater treatment, *Water* 2 (2010) (3) 530-549, doi: 10.3390/w2030530.

[3] H. Brix and C. Arias, Danish Guidelines for small-scale constructed wetlands systems for onsite treatment of domestuc sewage, *Water Sci. Tech.* 51 (2005) (9) 1-9.

[4] G. Vacca, H. Wand, M. Nikolausz, P. Kuschk and M. Kastner, Effect of plants and filter materials on bacteria removal in pilot-scale constructed wetlands, *Water Research* 39 (2005) (7) 1361-1373, doi: 10.1016/j.watres.2005.01.005.

[5] B. Gopal, Natural and constructed wetlands for wastewater treatment: potentials and problems, *Water Sci. Tech.* 40 (1999) (3) 27-35, doi: 10.1016/S0273-1223(99)00468-0.

[6] H. Wang, D. Jiang, Y. Yang and G. Cao, Analysis of chemical reaction kinetics of depredating organic pollutants from secondary effluent of wastewater treatment plant in constructed wetlands, *Wat. Sci. Tech.* 67 (2013) (2) 353-358, doi: 10.2166/wst.2012.521.

[7] S. Ávila, S. Estupiñan, A. Mejia and L. Mora, La calidad bacteriológica del agua del humedal Jaboque (Bogotá, Colombia) en dos épocas contrastantes, *Caldasia* 36 (2014) (2) 323-329, doi: 10.15446/caldasia.v36n2.47490.

[8] S. Jin, Y. Lin, D. Lee and T. Wang, Using constructed wetland systems to remove solids from highly polluted river water, *Wat. Sci. Tec.h: Water Supply* 1 (2001) (1) 89-96.

[9] J. García and A. Corzo, Depuración con Humedales Construidos. Departamento de Ingeniería Hidráulica, Marítima y Ambiental de la Universidad Politécnica de Catalunya, Barcelona, España, 2008.

[10] N. Khatiwada and C. Polprasert, Kinetics of fecal coliform removal in constructed wetlands, *Water Sci. Tech.* 40 (1999) (3) 109-116, doi: 10.1016/S0273-1223(99)00446-1.

[11] C. A. Arias, A. Cabello, H. Brix and N. H. Johansen, Removal of indicator bacteria from municipal wastewater in an experimental two-stage vertical flow constructed wetland system, *Wat. Sci. Tech.* 48 (2003) (5) 35-41.

[12] Y. Li, J. Yu, Z. Lui and T. Ma, Estimation and modeling of direct rapid sand filtration for total fecal coliform removal from secondary clarifier effluents, *Wat. Sci. Tech*. 65 (2012) (9) 1615-1623, doi: 10.2166/wst.2012.054.

[13] Z. W. Song, Z. P. Zheng and J. Li, Seasonal and annual performance of a full-scale constructed wetlands system for sewage treatment in China, *Ecol. Eng.* 26 (2006) (3) 272-282, doi: 10.1016/j.ecoleng.2005.10.008.

[14] G. Langergraber, A. Pressi and R. Haberl, Experiences from the full-scale implementation of a new two-stage vertical flow constructed wetland desing, *Wat. Sci. Tech.* 69 (2014) (2), 335-342, doi: 10.2166/wst.2013.708.

[15] R. Kadlec and S. Wallace, *Treatment Wetlands* (2nd ed.), United States of America: Taylor y Francis Group, 2008.

[16] M. P. Molleda, Aplicación de humedales construidos en la reducción de patógenos y otros contaminantes en agua residual urbana y ganadera. Tesis, Universidad de Leon, 2011, p.150.