IWA 17th International Conference on Wetland Systems for Water Pollution Control
6 – 10 November 2022, Lyon, France

Modified First Stage of French Vertical Flow Constructed Wetlands performance during extreme operation conditions

M. B. Arévalo-Durazno*,**, J. A. García Zumalacarregui**,***, L. Ho****, A. Narváez**, A. Alvarado**,*****

* Facultad de Ciencia y Tecnología, Universidad del Azuay, Av. 24 de Mayo 7-77 y Hernán Malo, Cuenca-Ecuador
(E-mail: *barevalo@uazuay.edu.ec)*
** Departamento de Recursos Hídricos y Ciencias Ambientales, Universidad de Cuenca, Av. Victor Albornoz y Calle de los Cerezos, Cuenca-Ecuador
(E-mail: *jorge.garciaz@ucuenca.edu.ec*, *carolina_narvaez96@ucuenca.edu.ec*, *andres.alvarado@ucuenca.edu.ec*)
***Facultad de Ciencias Agropecuarias, Universidad de Cuenca, Av. 12 de Octubre y Diego de Tapia, Cuenca-Ecuador
****Department of Animal Sciences and Aquatic Ecology, Ghent University, Coupure Links 653, Ghent-Belgium
(E-mail: *Long.TuanHo@ugent.be)*
***** Facultad de Ingeniería, Universidad de Cuenca, Av. Víctor Albornoz y Calle de los Cerezos, Cuenca-Ecuador.

Abstract
This study applied two Modified First Stage of French Vertical Flow Constructed Wetlands pilots for the treatment of sewage coming from a combined sewer system under extreme hydraulic loads and medium temperatures at high altitude. Particularly, the pilot-scale experiment was conducted within nine months after their start-up period of four months. During this period, two different high hydraulic loading rates (0.94 m d^{-1} and 0.56 m d^{-1}) representing 2.5 and 1.5 times the design values respectively, were applied to investigate the impact of HLRs on the performance of the treatment system. The observed performances for COD and TSS removals were satisfactory, with average values of 53% and 66% respectively. Moreover, reducing the HLR resulted in higher removal efficiency for COD (from 46% to 64%) but not for TSS (from 67% to 64%). From these findings, it is suggested that high HLRs can be applied for the First Stage of the French System without compromising the operation of the units and obtaining satisfactory results, especially in case of diluted wastewater and severe area restrictions.

Keywords
First Stage of French Vertical Flow Constructed Wetlands; Hydraulic loading rate; Municipal Wastewater; tropical Andes

INTRODUCTION

French Vertical Flow Constructed Wetlands (FVFCW) are a nature-based system that can treat sludge and wastewater in a single step in which wastewater percolates through a porous media and forms a sludge deposit layer on the top of the bed. The clogging of the system is controlled by its design with the considerations of rest and feed periods, together with adequate adjustment of hydraulic loading rates (HLR) and organic loading rates (OLR). Molle et al. (2005) recommended the wetlands to treat raw wastewater from separate networks, which resulted in design values of OLR≈ 300 g COD m-2 d-1 ≈ 150 g TSS m-2 d-1 and HLR of 0.37 m d-1. With this design, mean

efficiency values of 83% and 77% can be achieved for TSS and COD, respectively (Morvannou et al., 2015).

At the altitude of 2,500 m.a.s.l in Cuenca (Ecuador), we installed and operated a pilot-scale Modified First Stage of the FVFCW (FS-VCW) in order to treat raw wastewater derived from a combined sewer system. Specifically, testing the performance of the two pilots over 9 months at limit conditions, i.e. 0.94 and 0.56 m d-1 of HLRs, we aim to investigate (i) the performance of FS-VFCW treating combined domestic sewage in highlands and at medium temperatures; and (ii) if the wetlands can cope with high and extreme HLRs with still good efficiencies.

MATERIAL AND METHODS

Two pilot-scale wetlands were located in Cuenca (2°52′15.1′′S, 78°56′30.8′′ W) at the south Andes of Ecuador with an annual average temperature of 14°C. Each pilot had a superficial area of 9.81 m^2, with a length to width ratio of 1.3:1, and a depth of 1m with granular media of 0.7 m. The planted vegetation was *Lolium perenne.* Two HLRs were tested 0.94 m d^{-1} and 0.56 m d^{-1}. During nine months, the pilots were fed for three days and rested for six days. The feeding was done in batches of raw wastewater after passed through coarse screening and grit removal each hour (24 batches d^{-1}). Grab samples were collected for TSS and COD in the influent and effluent of the pilots in the second day of feeding and analysed according to standard methods. Experimental results were statistically analysed using R software. The Mann-Whitney U test was carried out first to probe that the two wetlands received the same influent in COD and TSS concentrations, and then for the comparison of the different HLR with removal efficiencies. Also, Spearman correlation was run for correlation between the COD and TSS loads with their removal efficiencies.

RESULTS AND DISCUSSION

Mean characteristics of the influent and effluent are presented in Table 1 without distinction between the two pilots. It shows the high variations of COD and TSS concentrations and the dilution of raw wastewater which can be explained by the type of sewer network. Despite these variations, the effluent concentrations complied with the Ecuadorian discharge standards to a freshwater body. As expected, the obtained removal efficiencies of 53% and 66% for COD and TSS respectively, were relatively low compared to those of the mature systems operating with lower HLRs, i.e. 83% and 77% (Morvannou et al., 2015). It is important to note that, as a result of the young age of the system and the hydraulic loads, the accumulated sludge layer was only about 1 cm in height near the inlets which however can also affect the system efficiency (Molle, 2014).

Table 1. Mean composition of influent and effluent from the pilots and removal efficiencies (number of data used COD: 58, TSS: 54)

	Unit	COD		TSS	
		Mean	SD	Mean	SD
Raw wastewater	mg L^{-1}	185	143	158	184
Effluent	mg L^{-1}	78	51	42	38
Removal efficiency	%	53	17	66	21

The HLR of the first stage of French System was recommended around 0.37 m d^{-1} corresponding to an organic load of 300 g COD m^{-2} d^{-1}, TSS load of 150 g SS m^{-2} d^{-1} and 1.2 m^2 Pe^{-1} for separated sewers (Molle et al., 2005). In this study, given the diluted influent, two high HLRs were applied, i.e. 2.5 times and 1.5 times higher than the recommended HLR (0.94 m d^{-1}, 0.56 m d^{-1},

respectively). Depending on the concentrations of the raw wastewater, the COD and TSS loads were variable with mean values of 178 g COD m^{-2} d^{-1} and 154 g SS m^{-2} d^{-1} for the HLR of 0.94 m d^{-1}; and 98 g COD m^{-2} d^{-1} and 82 g SS m^{-2} d^{-1} for the HLR of 0.56 m d^{-1}. Under these conditions, the removal efficiencies of COD and TSS were shown in Figure 1.

When testing the influence of HLR in the removal efficiencies, it showed that there was a significant difference in COD removal depending on the HLR ($p < 0.01$) while for TSS removal was not significant difference between the two HLRs applied ($p = 0.95$). For COD removal, the efficiency increases when the HLR decreases with a Spearman correlation coefficient of -0.49. The results obtained also showed that there was a correlation between TSS removal and TSS load ($p < 0.01$) while for COD removal and the COD load there was not significant correlation ($p = 0.65$).

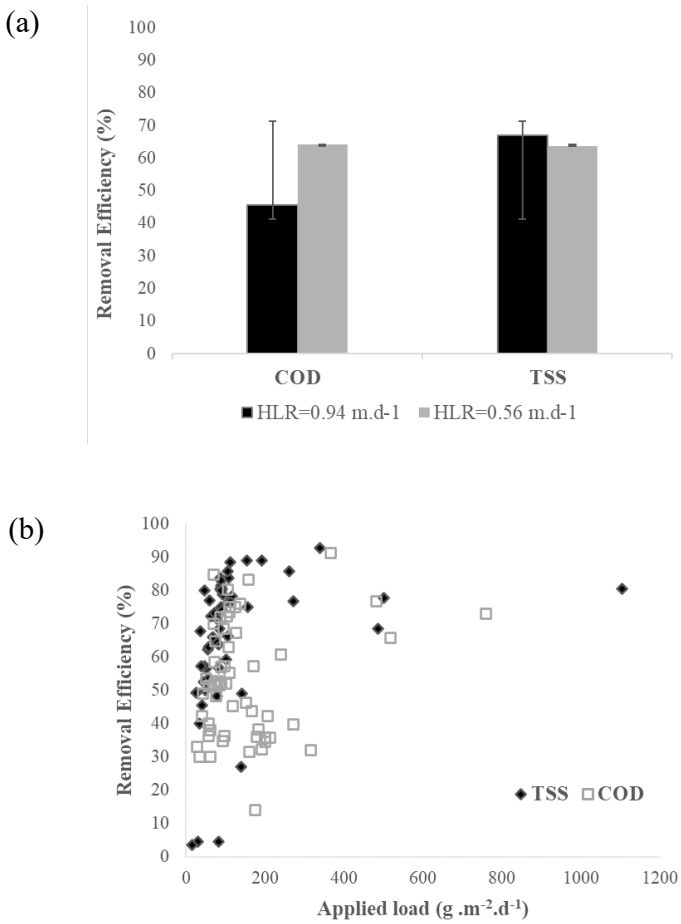

Figure 1. Removal efficiencies of COD and TSS (a) depending on the HLR applied, (b) depending on the load applied

By increasing the HLR without compromising the effluent quality (always below the Ecuadorian standards for free discharge in water bodies), the land requirement of the French VFCW can be reduced substantially, leading to lower investment cost which is a major bottleneck for wastewater treatment in many developing countries, especially in high Andean regions. Specifically, when increasing HLRs from 0.37 m d^{-1} to 0.56 m d^{-1} surface treatment of a French VFCW would reduce around 33% m^2 Pe^{-1} bed^{-1} and 60% m^2 Pe^{-1} bed^{-1} in case of 0.94 m d^{-1}. The percentages presented here correspond to conditions when the wastewater comes from a combined sewage system, which

should be considered for any comparison. These reductions in area represent an important economic aspect when choosing this type of wetlands for treating raw wastewater.

REFERENCES

Molle, P. 2014. A better understanding of the role of the deposit layer. *Water Science and Technology* **6**(1),106–112.

Molle, P., Liénard, A., Boutin, C., Merlin, G., & Iwema, A. 2005. How to treat raw sewage with constructed wetlands: An overview of the French systems. *Water Science and Technology* **51**(9), 11–21.

Morvannou, A., Forquet, N., Michel, S., Troesch, S., & Molle, P. 2015. Treatment performances of French constructed wetlands: Results from a database collected over the last 30 years. *Water Science and Technology* **71**(9), 1333–1339.