International Journal of Environment and Pollution Research
Vol.5, No.1, pp.1-7, March 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

PERFORMANCE EVALUATION OF THREE NATIVE PLANTS FOR SEWAGE WASTEWATER TREATMENT IN CONSTRUCTED WETLAND

Cuong, Nguyen Xuan; Loan, Nguyen Thi

***Cuong, Nguyen Xuan**, Faculty of Environmental engineering technology, Hue University, Quang Tri Campus, Dong Ha City, Vietnam*

ABSTRACT: *Sewage wastewater was tested the purifying capacity by three constructed wetlands planted with Caladium bicolor (HF_1), (Colocasia esculenta) (HF_2), (Dracaena sanderiana) (HF_3) and HF_4 unplanted. HF_s were loaded with two hydraulic load rates (HLR) at 0.05 m/d and 0.1 m/d. The planted tanks obtained bigger mean removal of total suspended solid (TSS), biochemical oxygen demand (BOD_5) but not clearly with nutrients and total coliform (Tcol). HF planted with Caladium bicolor reached the higher than other HF_s in terms of mean removal efficiency, stable and growth of shoots and roots. The mean removal for HF planted ranged 42 – 50% of BOD_5, 50 – 53% of TSS, 22 – 31% of ammonia (NH_4-N), 49 – 52% of nitrate (NO_3-N), 2 – 8% of phosphate (PO_4-P) and 75 – 81% of Tcol. The effluent concentrations met Vietnam's standard apart from some samples at 0.1 m/d passed the discharge limit for BOD_5 and Tcol concentrations.*

KEYWORDS: constructed wetland, native plant, sewage wastewater

INTRODUCTION

White some sewage treatment plants have been built in large cities in Vietnam, untreated wastewater in smaller towns is still released directly into water body, and Dong Ha city - Quang Tri province is good case for this. Almost municipal wastewater plants in Vietnam have used activated sludge methods with mainly foreign loans (WB, 2013) which may not be feasible for small city like Dong Ha. These procedures have conclusively shown many negatives such as big capital, complex construction and skilled labor operation, sensitive to inlet, excessive sludge, and violations of discharge standards (Simi and Mitchell, 1999, Sayadi et al., 2012, USEPA, 2000).

In that situation, a technology as constructed wetland which have been considered as eco-friendly, cost effective and alternative technology (Crites and Ogden, 1998, Kadlec and Wallace, 2009, Babatunde et al., 2008, Toscano et al., 2009) can give a potential solution for Dong Ha wastewater issue. In tropical areas like Vietnam, there are more local native plants which contain a large potential for using in constructed wetland. Some of them are *Caladium bicolor*, *Colocasia esculenta and Dracaena sanderiana* that cultivate easily and adapt with wet and polluted conditions. Besides the purifying potential, these plants can bring other benefits like animal feed and landscape improvement that have not been studied yet in constructed wetland.

ISSN 2056-7537(print), ISSN 2056-7545(online)

This study aims: To assess the treatment efficiency of HF_s planted with *Caladium bicolor*, *Colocasia esculenta and Dracaena sanderiana* and unplanted under short HRT and comparing with discharge limits set to effluent of system;

MATERIALS AND METHODS

Experimental setup

The lab scale HF_s (Figure 1) were situated at Hue University – Quang Tri Campus, Vietnam (16°48′24″N 107°05′48″E). The experiment runs for 5 months in which first two months for planting trees and adaptive operation, and 3 months for monitoring during May – August 2015. The experimental system included 4 horizontal flow tanks and planted with elephant ears (*Caladium bicolor)*, which is a food crop and fodder (HF_1), taros (*Colocasia esculenta)* - ornamental plant (HF_2), lucky bamboos (*Dracaena sanderiana)* - ornamental plant (HF_3). HF_4 run as the control tank without plant (Figure 2). These trees were bred from local home garden and watercourses as samplings (15 - 20 cm height and 2 – 5 cotyledons) and raised adaptively in HF_s for two months. Planting density was 20 - 25 plants per square meter. Three uniform gravel layers of grain size 1 – 4 mm were set to provide a depth of 0.4 m. The porosity of the media was 0.4.

The system operated with two stages corresponding two HLR_s: First stage at 0.05 m/d (HLR_1), second period at 0.1 m/d (HLR_2) (1.5 months for each stage). HRT ranged 0.3 to 0.6 days. The inlet was provided continuously from storage tank collected from sewage wastewater.

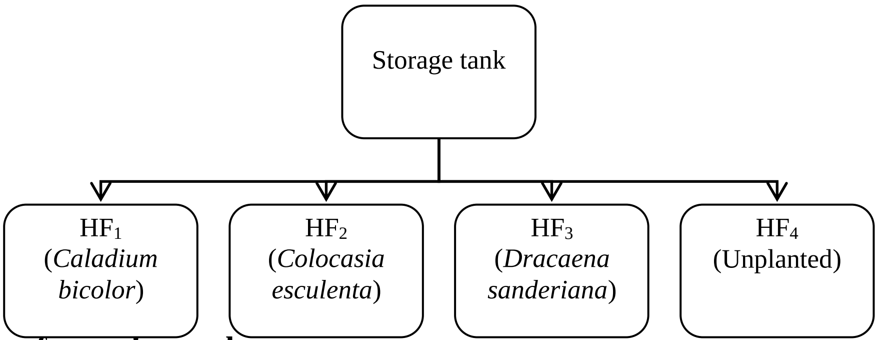

Figure 1: Schema of experimental setup

Figure 2: Picture of *Caladium bicolor* (left), *Dracaena sanderiana* (middle) and *Colocasia esculenta* (right)

ISSN 2056-7537(print), ISSN 2056-7545(online)

Sampling procedure and analyses

Samples collected twice a week of inlet (one sample) and outlets of each HF (4 samples). The analyzed parameters include: pH, BOD_5, TSS, NH_4-N, NO_3-N, PO_4-P and Tcol. All analyses were accomplished according to APHA/WEF/AWWA (2005). Two samples were used for each analysis and the results were averaged.

Statistical tests

The data of system was managed and tested by R software (Version R i 386 3.2.2). The statistical differences of the experimental results were evaluated by ANOVA and post-hoc test (Tukey HSD) was used to compare multiple of means 95% confident level.

RESULTS AND DISCUSSION

Table 1: Removal efficiency of horizontal flow constructed wetlands

Parameter	HF_1	HF_2	HF_3	HF_4
	E (%±SD)	E (%±SD)	E (%±SD)	E (%±SD)
TSS	50±12	50±14	53±12	49±10
BOD_5	50 ±13	42 ± 13	45± 10	39±16
NO_3-N	50 ± 22	49 ± 21	52±21	52±20
NH_4-N	22±21	30±16	31±27	22±34
PO_4-P	8±24	2±36	5±39	3±38
Tcol	81±17	75±30	81±26	81±19

The mean removal efficiency for BOD_5 obtained highest in HF_1 planted *Caladium bicolor* (50%) while biggest TSS removal rate was in HF_3 planted *Dracaena sanderiana* (53%) (Table 1). The effluent concentrations of TSS of all HF_s were lower than 97 mg/l which met Vietnam standard (QCVN 14:2008/BTNMT for domestic wastewater – column B, 100 mg/l). BOD_5 effluents ranged from 22 to 67 mg/l and reached lower treatment efficiency in HF_4 (unplanted) in terms of mean and Q_1 (25^{th} percentile), Q_3 (75^{th} percentile) values of box plot (Figure 3). Some samples passed the discharge limit for BOD_5 concentration at loading rate of 0.1 m/d (50mg/l) of all HF_s. In general, 75% BOD_5 effluents in HF_1 and HF_3 were lower than discharge standard but HF_1 contained the outlier at 81 mg/l. While BOD_5 effluent of HF_2 remained quite high value that might reflect the low treatment efficiency of 42% in comparison with 45% of HF_3 and 50% of HF_1.

On the mean side, plants effected to TSS and BOD_5 removal efficiency which planted tanks obtained higher value, especially with BOD_5. However, there is no statistically significant difference between the effluents (and removal efficiencies) of all HF tanks (P = 0.2 – 0.9).
Hydraulic loading rates effected to removal rate which BOD_5 and TSS effluents showed higher value when HLR rising. Tukey HSD test demonstrated the BOD_5 effluents between HLR_1 and HLR_2 differed significantly ($P < 0.05$). The former studies indicated that correlation was not clear (Vymazal and Kröpfelová, 2015, Melian et al., 2010, Foladori et al., 2012).

ISSN 2056-7537(print), ISSN 2056-7545(online)

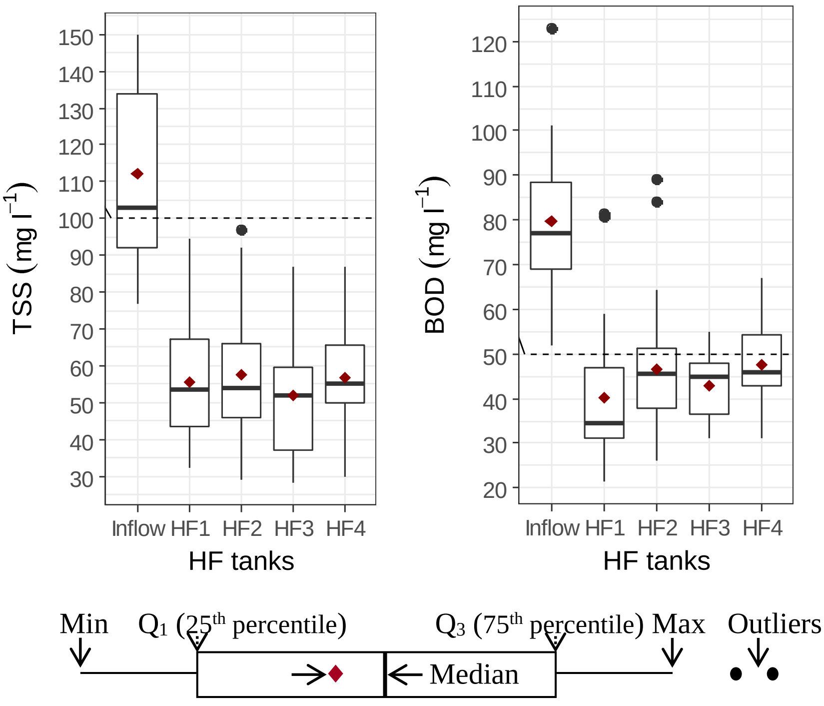

Figure 3: Influent and effluent of TSS and BOD from HF tanks

Note: line (……): Vietnam's standard (QCVN 14:2008/BTNMT)

Compared to HF_s planted common reeds (*Phragmites)* and cattails (*Typha)* which are familiar plants for wastewater treatment, this study obtained same or lower removal efficiency for BOD_5. With HF planted *Phragmites karka*, treatment efficiency of BOD_5 reached 67% at 0.08 m/d and 50% at 0.2 m/d (Pandey et al., 2013). Mean efficiency of BOD_5 of HF planted *Typha* was 79% at 0.15 m/d and 0.075 m/d, and HF planted *Phragmites* obtained 78% at 0.075 m/d and 87.5% at 0.15 m/d (Solano et al., 2004). HF planted *Typha latifolia* and operated at 0.1 m/d amounted 63% of BOD_5 removal (Dornelas et al., 2009). With longer HRT (6 to 20 days), Akratos and Tsihrintzis (2007) reported 88.3% and 84.5% removal of BOD_5 obtained in HF planted *Typha latifolia* and HF planted *Phragmites australis*, respectively.

Figure 4 shows that the effluent concentrations of NO_3-N and NH_4-N of HF_s planted were quite similar with HF_4 (unplanted). The removal rate of NH_4-N in HF unplanted reached the same result with HF_1 (22%) and lower than HF_2, HF_3 (30 – 31%) while NO_3-N treatment efficiency obtained the highest value in HF unplanted and HF_3 with 52%. NH_4-N concentrations were probably more stable in HF planted. The removal of NO_3-N (49-52%) reached higher than NH_4-N (22-31%) because the denitrification process in HF was prevalent than nitrification (less oxygen, adequate carbon) (Table 1). The different plants and tanks did not influence more to the removal efficiency of nutrients (P>0.05).

In comparison with HF_s planted some popular trees, NH_4-N removal rates in this study are middle. With similar HLR, HF planted *Typha latifolia* at 0.1 m/d obtained 2% of NH_4-N removal (Dornelas et al., 2009) while Pandey et al. (2013) reported 49.9% at 0.08 m/d and 37.9% at 0.2 m/d in HF planted *Phragmites karka*. With longer HRT, previous studies showed the higher removal rates of NH_4-N. 36.2% and 53.6% removal of NH_4-N obtained in HF (6 –

ISSN 2056-7537(print), ISSN 2056-7545(online)

20 days) planted *Typha latifolia* and HF planted *Phragmites australis*, respectively (Akratos and Tsihrintzis, 2007).

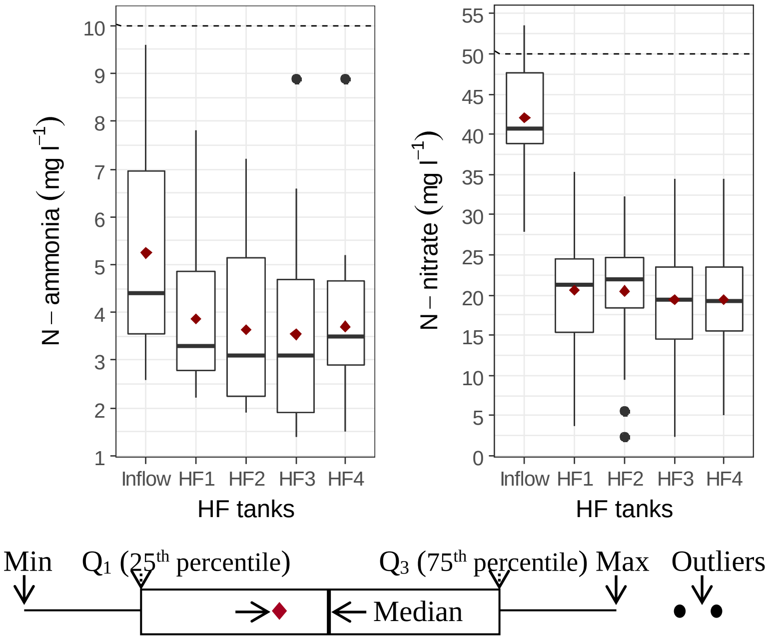

Figure 4: Nitrogen concentration of HF tanks

Note: line (……): Vietnam's standard (QCVN 14:2008/BTNMT)

PO_4-P removal efficiencies of HF planted and unplanted were low (Table 1) and with no significant difference of effluents among HF tanks (P = 0.7 - 0.9). The normal and big sized gravel might be a main explanation for low PO_4-P reduction (Vymazal and Kröpfelová, 2015). Tcol effluent concentrations were unstable with more outliers and no significant difference among HF tanks (P = 0.8 - 1.0). However, mean effluent of Tcol in HF_1 planted *Caladium bicolor* and HF_4 unplanted were higher than others with 5.000 MPN/100ml (Figure 5). Table 1 show that HF planted obtained less efficiency or similar to HF unplanted which might be contrary to Dornelas et al. (2009) reporting with HF planted *Typha latifolia* and HF unplanted (HLR 0.1 m/d) obtained 97.5% and 91.2% of Tcol removal, respectively or 3.1 log unit of removal in HF planted *M. aquatic* and 2.2 in HF unplanted revealed by Avelar et al. (2014). With HRT of 4 days, HF planted *Zantedeschia aethiopica* reached 93.1% of Tcol removal rate (Zurita et al., 2009).

ISSN 2056-7537(print), ISSN 2056-7545(online)

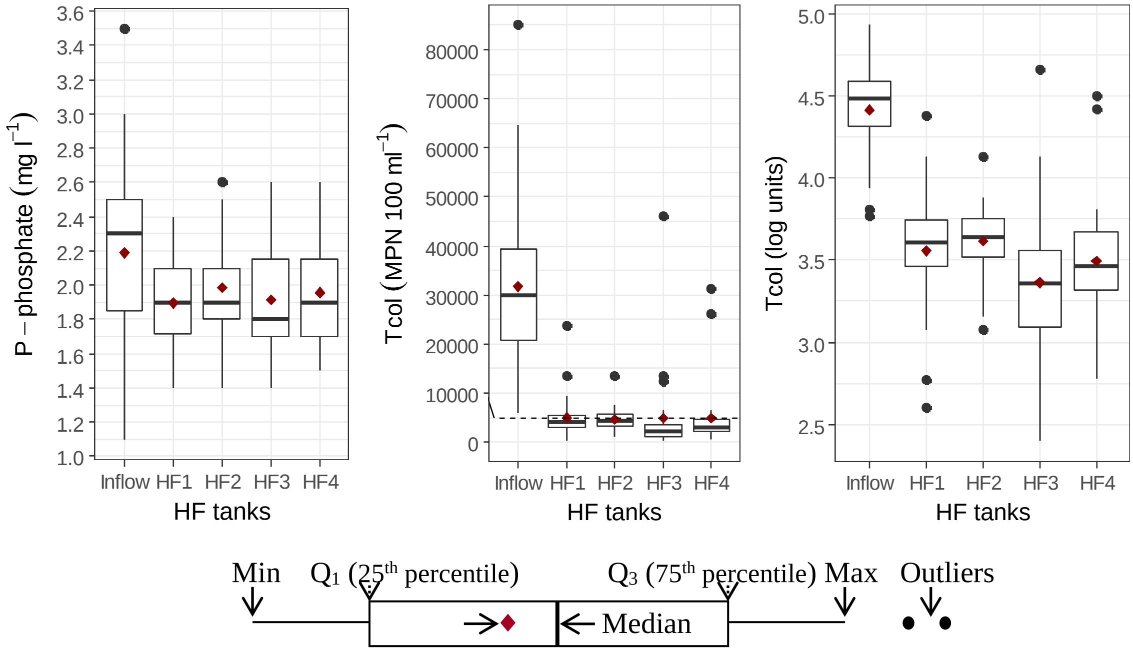

Figure 5: Phosphate and Tcol concentrations of HF tanks

CONCLUSIONS

HF_s fed continuously considered as less dissolved oxygen and reached limit of NH_4-N removal rate due to low nitrification. *Caladium bicolor* grew faster than other plants in HF (in terms of shoots and roots) and all attained the state of mature after 2 months. In general, HF planted with *Caladium bicolor* obtained high and stable efficiency for all parameters (50% of TSS, BOD_5 và NO_3-N; 22% of NH_4-N and 81% of Tcol). All samples in first stage met well with discharge standards while with second period some effluents passed limits. Short HRT (0.3 – 0.6 days) in this study did not probably provide sufficient contact time between the wastewater and biofilm in HF_s which obtained a medium removal efficiency of BOD_5 and nutrients. Denitrification and nitrification processes in HF_s were quite complicated and influenced by more factors, therefore, no clear trend of NH_4-N, NO_3-N removal among HF planted and unplanted. HLR rising gave to higher of mass loading rate efficiency but facing to limits of discharge, therefore HLR of 0.05 or 0.75 m/d might be suitable for standard design of a real constructed wetland.

REFERENCES

Akratos, C. S. & Tsihrintzis, V. A., (2007), Effect of temperature, HRT, vegetation and porous media on removal efficiency of pilot-scale horizontal subsurface flow constructed wetlands, *Ecological Engineering*, **29,** 173–191.

APHA/WEF/AWWA, (2005), Standard Methods for the Examination of Water & Wastewater, Centennial Edition. 21 ed, American Public Health Association, the American Water Works Association, and the Water Environment Federation, Washington DC

ISSN 2056-7537(print), ISSN 2056-7545(online)

Avelar, F. F., Matosa, A. T., Matosb, M. P. & Borges, A. C., (2014), Coliform bacteria removal from sewage in constructed wetlands planted with Mentha aquatica, *Environmental Technology,* **35,** 2095–2103.

Babatunde, A. O., Zhao, Y. Q., O'neill, M. & O'sullivan, B., (2008), Constructed wetlands for environmental pollution control: a review of developments, research and practice in Ireland, *Environment International*, **34,** 116-126.

Crites, R. W. & Ogden, M., (1998), *Cost of constructed wetlands systems,* WEFTEC, Water Environmental Federation, Orlando, US, 7, 293-302.

Dornelas, F. L., Machado, M. B. & Sperling, M. V., (2009), Performance evaluation of planted and unplanted subsurface-flow constructed wetlands for the post-treat ment of UASB reactor effluents, *Water Science & Technology*, **60,** 3025-3033.

Foladori, P., Ortigara, A. R. C., Ruaben, J. & Andreottola, G., (2012), Influence of high organic loads during the summer period on the performance of hybrid constructed wetlands (VSSF - HSSF) treating domestic wastewater in the Alps region, *Water Science & Technology*, **65** 890-897.

Kadlec, R. H. & Wallace, S. D., (2009), *Treatment wetlands,* CRC Press, Florida.

Melian, J. A., Rodríguez, A. J., Arana, J., González Díaz, O. & González Henríquez, J. J., (2010), Hybrid constructed wetlands for wastewater treatment and reuse in the Canary Islands, *Ecological Engineering*, **36,** 891-899.

Pandey, M. K., Jenssen, P. D., Krogstad, T. & Jonasson, S., (2013), Comparison of vertical and horizontal flow planted and unplanted subsurface flow wetlands treating municipal wastewater, *Water Science & Technology*, **68,** 117-123.

Sayadi, M. H., Kargar, R., Doosti, M. R. & Salehi, H., (2012), *Hybrid constructed wetlands for wastewater treatment: A worldwide review,* International Academy of Ecology and Environmental Sciences, IAEES, 204-222.

Simi, A. & Mitchell, C., (1999), Design and Hydraulics Performance of a Constructed Wetland Treating Oil Refinery Wastewater, *Water Science and Technology,* **40,** 301-307.

Solano, M. L., Soriano, P. & Ciria, M. P., (2004), Constructed Wetlands as a Sustainable Solution for Wastewater Treatment in Small Villages, *Biosystems Engineering,* **87,** 109–118.

Toscano, A., Langergraber, G., Consoli, S. & Cirelli, G. L., (2009), Modelling pollutant removal in a pilot-scale two-stage subsurface flow constructed wetlands *Ecological Engineering,* **35,** 281–289.

USEPA, (2000), *Constructed Wetlands Treatment of Municipal Wastewaters,* United States Environmental Protection Agency, USA.

Vymazal, J. & Kröpfelová, L., (2015), Multistage hybrid constructed wetland for enhanced removal of nitrogen, *Ecological Engineering,* **84,** 202–208.

WB, (2013), *Vietnam - Urban wastewater review: Executive summary,* World Bank, Washington DC.

Zurita, F., De Anda, J. & Belmont, M. A., (2009), Treatment of domestic wastewater and production of commercial flowers in vertical and horizontal subsurface-flow constructed wetlands, *Ecological Engineering,* **35,** 861–869.

ISSN 2056-7537(print), ISSN 2056-7545(online)