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Wastewater Treatment through Ornamental Plants: A Review

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Abstract

This review deals with two untreated wastewater types, including domestic wastewater (in tourist destinations) and pharmaceutical industry wastewater, to shed light on the efficiency of constructed wetlands (CW). In mountainous areas, it has always been difficult to have a proper sewage treatment and disposal system for which a proper method is proposed in this paper. In CW, toxic materials should be removed from the water for which a surface CW layer is constructed. Ornamental plants (*Canna flaccida, Zantedeschia aethiopica*, and *Canna indica*) were used in this study and they showed usefulness in reducing 80% of BOD (biological oxygen demand) and COD (chemical oxygen demand). Carbamazepine is a pharmaceutical drug that is widely used and pollutes aquatic environments when it is discharged untreated. This problem can be solved by constructing a horizontal subsurface flow wetland in which the vertical subsurface flow in the wetland is considered and the wastewater is then stabilized in ponds. Three different ornamental species were used (*Thypha latifolia, Iris sibirica*, and *Zantedeschia aethiopica*) and their performance was explored on parameters like dissolved oxygen, pH, oxidation/redox potential (Eh) whose average mass removal was 62.5 ± 4.5% and 59.0 ± 4.5%, respectively. The results showed the amazing performance of the two former species. The ornamentals used to get the flowers for commercial production included *Zantedeschia aethiopica*, *Strelitzia reginae*, *Anthurium andraeanum* and *Agapanthus africanus*. After the system was supplied with the target wastewater, *Zantedeschia aethiopica* grew about 60 flowers and maintained a healthy outlook while other species grew large leaves, and some died due to the harsh environmental conditions. The reviewed data depicts that *Canna indica* gave great results for the BOD and COD removal with *Z. aethiopica* having the potential of giving a greater number of flowers while tolerating the weather conditions. However, for carbamazepine, two species that could take up the pollutants were found to be *Iris sibirica* and *Zantedeschia aethiopica*.

Keywords: Constructed wetland, Domestic wastewater treatment, Ornamental plants, Pharmaceuticals drug (carbamazepine).

INTRODUCTION

The use of water in every aspect of life necessitates it to utilize all water circles growingly. Domestic and industrial water use, as well as water use in dairy farms and other important parts of society, have placed unexpected pressure on water resources and have caused the production of a huge amount of wastewater. In addition to these water uses, mountainous areas host tourists, which aggravates the situation further (Coleman *et al*., 2001; Karathanasis *et al.*, 2003). Ornamental plants including certain species (*Canna flaccida, Zantedeschia aethiopica, Canna indica, Agapanthus africanus* and *Watsonia borbonica*) have the potential to reduce BOD, COD, and NH_4^+ of the wastewater. Pharmaceuticals have always been increasingly used all over the world with some changing patterns due to the spread of diseases. This industry uses some chemicals that do not degrade easily and sometimes persistently stay in nature, one of chemical is an antiepileptic drug, carbamazepine. These chemicals reach the aquatic life, left untreated in the developing nations (Zhang *et al*., 2011).

The proper domestic use and discharge after an initial treatment is lacking in developing countries mostly in rural areas and then in urban areas whereas they typically have their treatment plants. This huge amount of water can be reused for the gardening purpose if treated with the ornamental plant species (*Colocasia esculenta* and *Canna indica*) in the form of vertical flow or free-water surface in constructed wetlands (CWs) (Cuong Nguyen *et al*., 2020). In Vietnam, municipal authorities have constructed some treatment plants, but most of the domestic or dormitory sewage water is discharged untreated. If *Canna indica* is used in less populated areas with hydraulic loading rate (HLR) (0.02–0.12 m/d) for water treatment, the water can be applied for the irrigation purposes whose results are reported in the study (Ávila *et al*., 2013).

The constructed wetland (CW) is an environmentally friendly way to get rid of pollutants. It also has many benefits, e.g., if you have ornamental species that can tolerate climatic conditions, they can flower. Another huge advantage of CWs is that they can be cost-effective as compared to other mechanical solutions available. Some ornamental species (*Strelitzia reginae*, *Anthurium andreanum* and *Agapanthus africanus*), which grow beautiful flowers have performed well in CWs. Also, *Zantedeschia aethiopica* can produce 60 flowers and healthier leaves when used for the treatment of specific wastewater. These species can eventually reduce huge amount of pollutants by their biological uptake. It has been observed that these plants have recorded huge amounts of removal, such as 80% of BOD and 50.6% of COD and statistically significant results have even been reported for NO_3^- reduced by 47.7% and TSS reduced by 82% (Vymazal, 2002; Senzia, 2003; Liu *et al*., 2005).

LITERATURE REVIEW

The domestic use of water in most situations is made by septic tanks. A study was conducted in Portugal on the guest houses in a rural area have septic tanks, as well as designs on earth work, i.e., CW, according to standards. As water absorption capacity plays an important role, it was designed with respect to the European standards. In CWs, during construction phase, some coarse layers are embedded between the layers to facilitate the discharge of effluent after passing through the roots and prevent its infiltration into the groundwater. All experiments were carried for 6 months in which several ornamental plants (*Canna flaccida*, *Zantedeschia aethiopica, Canna indica* and *Agapanthus africanus*) were used for the purposes. Interestingly, the presence of these plant species in the environment increased diversity in the region, which is itself an advantage of CWs. Then, wastewater samples were collected from both the inlet and outlet of the CW to measure COD, BOD, nitrogen, phosphorous, and aluminum. Colorimetric methods were used to measure N and P while the titrimetric method was used for Al measurement. The t-test was performed for the statistically significant results using SPSS software (IBM Corp., Released, 2012; IBM SPSS statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.).

The pharmaceutical drug named carbamazepine, which is widely used, harms aquatic environment when discharged as effluent. To remove this medication by the CW, before the water entered a tank, it was added with carbamazepine at a rate of 25 $\mu g\ L^{-1}$ of purity 99% (Zurita and

White, 2014). The process is divided into three systems including HSSF-CW, SP, HSSF-CW followed by a VSSF-CW and the last VSSF-CW and finally, HSSF-CW (Fig. 1).

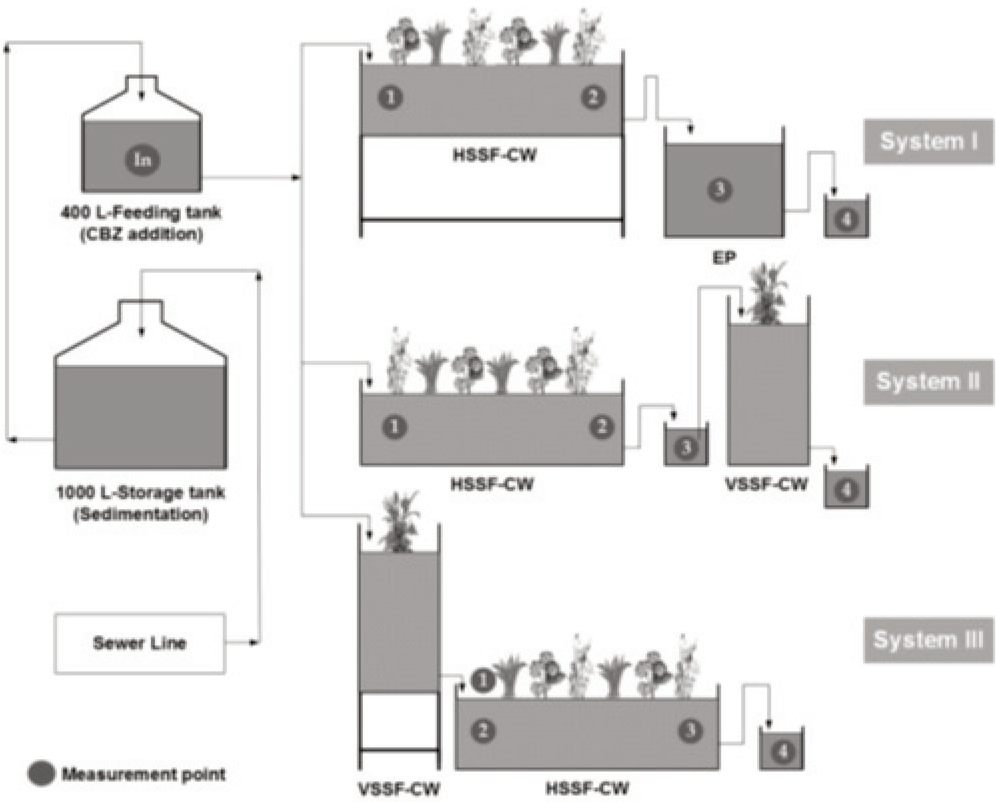

Fig. 1. The hybrid system used for the experiment (Tejeda *et al*., 2016).

Then, each of the HSSF-CW was introduced by three ornamental species in polyculture for the number of microorganism (Karathanasis *et al*., 2003; Vacca *et al*., 2005; Zurita *et al*., 2009). The system was run for three months to achieve the stabilization in the CW after which carbamazepine (CBZ) was added into it. Then, CBZ was quantified on samples on a daily basis. It was detected to be 0.47 ± 0.00 g L^{-1}. Then, this inlet and outlet water was subjected to the measurement of parameters including COD, BOD, TSS, total P and other parameters. CBZ mass removal efficiencies were checked followed by the performance of the polyculture plants used in the experiment. The CBZ mass balance was estimated by the following equation (Tejeda *et al*., 2016).

CBZ (mass-in) = CBZ (mass-out in the effluent + CBZ (in plants) + CBZ mass removal by other mechanisms.

Finally, the statistical analysis of ANOVA was used to check for the significance of the results at the 2^{nd} end of the CW.

RESULTS AND DISCUSSION

The CW placed in a guest house after septic tank gave us great results in terms of excellent flowers and the shoot size of the ornamental species. While the shoot size was increased by five times in *C. flaccida* and by three times in *Z. aethiopica* and *C. indica*, *A. Africanus* grew less (Fig. 2). The temperature of the inlet and outlet water changed as it came out of the CW and it was observed that 80% of BOD and COD were removed (Table 1).

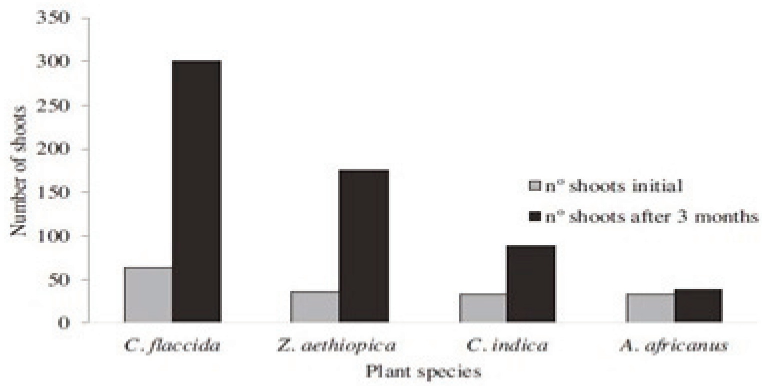

Fig. 2. The shoots of different plants with size.

Table.1. Effluent different parameters data (Cristina *et al*., 2015).

Parameter (no. of samples)	Average (min-max)	
	Inlet	Outlet
pH (n=22)	6.95 (6.13-8.04)	7.40 (7.00-7.84)
EC (dS m^{-1}) (n=22)	0.64 (0.08-2.12)	0.46 (0.14-0.89)
COD (mg L^{-1}) (n=24)	481 (20-1467)	30 (3-78)
BOD (mg L^{-1}) (n=24)	182 (10-480)	11 (2-30)
TSS (mg L^{-1}) (n=21)	283 (10-1500)	14 (3-39)
(mg -PL^{-1}) (n=20)	19.1 (1.5-98.2)	5.2 (0.8-10.4)
(mg -NL^{-1})(n=20)	21.6 (2.7 – 75.3)	12.2 (1.9-41.9)
(mg -NL^{-1})(n=20)	1.5 (0.1-7.4)	0.1 (0.1-0.3)
(mg -NL^{-1})(n=20)	16.6 (0.1-37.0)	2.0 (0.1-9.4)

The three systems used for carbamazepine showed different dissolved oxygen (DO) concentrations as it was low in the 1st phase due to the less availability of the sunlight and algae growth while the DO concentration was comparatively higher in the 2nd stage, reaching 2 mg/L observed, which means better aerobic situation (Fig. 3.). Also, the redox potential and pH also showed the results that can be interpreted as the initiation of the decrease in BOD (Kadlec and Wallace, 2009). Indeed, pH affects the absorption and performance of the microorganisms directly and it was observed that pH reached near 8. This is due to the HSSF-CW buffer capacity and algae growth (Kadlec and Wallace, 2009).

The three systems (S1, S2, and S3) showed different results in which the 1st and 2nd had more removal efficiency than the 3rd one. In S2, the removal efficiency was 49%, which was increased by 10% in the VSSF-CWs. All these reports of CBZ are in agreement with reports of other authors for their degradation (Park *et al*., 2009) (Table 2).

CONCLUSION

The present combined study upon this topic revealed the high rate of adaptability of CWs for the solution of wastewater treatment. In the foremost, it shows a comprehensive way to deal with wastewater treatment in rural sites or remote areas for adapting this as it also caters the fluctuations in the loading rate. It also bestows an aesthetic value to the environment and biodiversity. It can be implemented for a single house or even a central point. *Z. aetiopica* and *I. sibirica* both are efficient for carbamazepine reduction as removal and polyculture/hybrid technique is valuable for removing the drugs depending upon the climate.

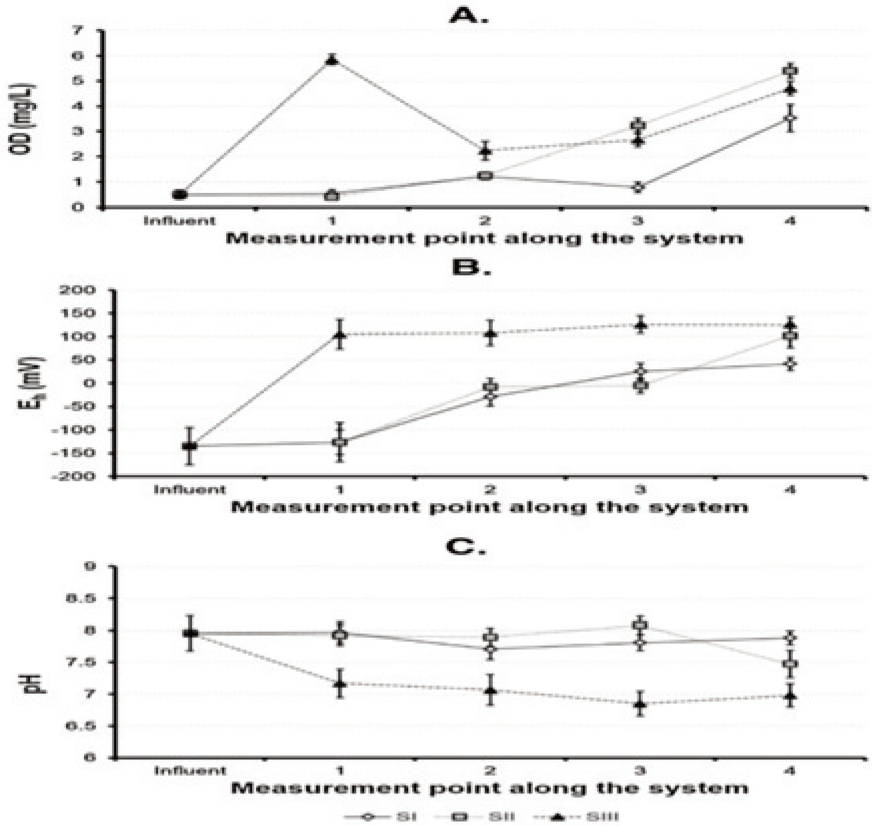

Fig. 3. The polyculture grown parameters data.

Table 2. CBZ concentration in 3 systems and the evaluation of the system.

CBZ concentration in the three system, along the period of evaluation (Average ± Standard Error of the Mean)

	Influent	SYSTEM I: HF-SP		SYSTEM II: HF-VF		SYSTEM III: VF-HF	
		1st stage HF-CW	2nd stage SP	1st stage HF-CW	2nd stage VF-CW	1st stage VF-CW	2nd stage HF-CW
CBZ concentration ($\mu g\ L^{-1}$)	25.0±0.01	13.13±0.05	9.32±0.05	12.87±0.04	10.12±0.04	13.30±0.05	12.76±0.06

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