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Comparing the Efficiency of *Cyperus alternifolius* and *Phragmites australis* in Municipal Wastewater Treatment by Subsurface Constructed Wetland

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Abstract: Nowadays, application of natural wastewater treatment systems such as wetland not only reduces economic costs and energy consumption, but also decreases environmental pollution. This study aimed to compare efficiency of *Cyperus alternifolius* and *Phragmites australis* in Municipal wastewater treatment by Subsurface Constructed Wetland Method. This is an applied-interventionnal study in which three reactors (control pilot, *Cyperus alternifolius* (umbrella palm) plant pilot and *Phragmites australis* (reed) plant pilot were designed by subsurface constructed wetland method. Then 90 samples were taken from input and output of reactors with four-day retention time. These samples were tested and finally the data were analyzed by Paired Sample Test statistical analysis. The results showed that removal efficiency of the parameters such as COD, BOD_5 , TSS , NO_3-N, NH_3-N, PO_4-P, total coliform and fecal coliform was 74, 73, 84, 40, 36, 70, 33 and 38% in *Cyperus alternifolius* plant wetland, 44, 34, 77, 15, 0.3, 1, 17 and 26% in control wetland and 59, 54, 73, 6, 3, 10, 93 and 50 in *Phragmites australis* plant wetland, respectively. This reduction rate in all parameters- except fecal coliform- was statistically significant (p = 0.05). The results of this study showed that *Cyperus alternifolius* plant had higher efficiency in the removal of chemical parameters, whereas *Phragmites australis* plant had appropriate efficiency in the removal of microbiological parameters. Therefore, it can be concluded that application of these two plants can be effective in wastewater treatment.

Key words: Constructed Wetland , *Cyperus alternifolius*, *Phragmites australis*, wastewater treatment

INTRODUCTION

Increasing world population has led to the emergence of many problems for human being. One of these problems is environmental pollution, especially pollution of water resources by wastewater. This not only causes environmental hazards, but also threatens human health (Vega *et al*., 2003). Municipal or domestic wastewater is one of the major sources of environmental pollution that imposes a heavy cost on economy of the countries (Tchobanoglous *et al*., 2003). Today, there is a wide range of wastewater treatment systems; however, most of these systems have major problems, including high manufacturing costs, high energy consumption and complex operation which need sludge treatment and disposal. In most countries, high technology systems with high costs are used for wastewater treatment the implementation of which requires large amount of money and investment. On the other hand, application of natural low-tech wastewater treatment systems such as Constructed Wetland (CW) not only reduces economic costs and energy consumption but also decreases environmental pollution(El-Khateeb *et al*., 2009; Ye and Li, 2009). Natural wastewater treatment systems use physical, chemical and biological processes which are caused by interactions of water, soil, plants and microorganisms in nature (Maine *et al*., 2007; Cheng *et al*., 2009). Constructed Wetlands are considered as cost effective as well as wise-economic method in wastewater treatment due to their simple and inexpensive operation and maintenance. Thus, they can be used in developing countries which are faced with water pollution problem that is caused by wastewater (Mantovi *et al*., 2003; O'Neill *et al*., 2011). The Constructed Wetlands can be used to attain these objectives: domestic wastewater treatment and agricultural runoff, industrial wastewater

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treatment, landfill leachate treatment, flood treatment and urban runoff, post treatment of wastewater, restoration of autotrophic lakes and treatment of water polluted by nutrients such as nitrate and phosphate (Moore *et al*., 2000; Kivaisi, 2001; Hadad *et al*., 2006; Vymazal, 2007, 2010; Chung *et al*., 2008). Constructed Wetlands are used to treat variety of pollutants available in wastewater including organic materials, detergents, nitrogen and phosphorus compounds, heavy metals, suspended solids and trace elements in wastewater such as copper, zinc, aluminum, etc. (Kadlec, 1999; Chung *et al*., 2008; Kropfelova *et al*., 2009). Constructed Wetlands can also be used as a final treatment process after biological treatment processes, such as stabilization ponds (Belmont *et al*., 2004). In general, there are two types of Constructed Wetlands: Free Water Surface wetlands (FWS) and Sub-Surface Flow wetlands (SSF). Wastewater flow can be in upward vertical mode or horizontal mode in subsurface wetlands. Subsurface wetlands' bed is filled with gravel, sand and proper grading soil. This bed provides an appropriate platform for growth of bacteria. Moreover it leads to high settlement of pollutants (Thurston *et al*., 2001; Lee *et al*., 2009). The most important part of wastewater treatment mechanism in wetlands is presence and activities of aquatic plants and microorganisms as well as transportation of oxygen from the air to plant's roots (Armstrong *et al*., 2000; Nwuche and Ugoji, 2008; Nwuche and Ugoji, 2010; Di Luca *et al*., 2011). Studies show that fenny aquatic plants directly and indirectly play an important role in wastewater treatment. These plants transport oxygen to roots, absorb nutrients and directly decompose pollutants (Stottmeister *et al*., 2003; Cheng *et al*., 2011). Reed plant or *Phragmites australis* is one of the most common fenny aquatic plants used in Constructed Wetlands, so that in most of studies wetlands are simply known with this plant. Other fenny aquatic plant used in wetlands is umbrella palm or *Cyperus alternifolius*. This plant has long, thin and green leaves which grows up to one meter in good condition. It also has strong roots and grows fast. This plant can be used for wastewater treatment in wetland method (Liao *et al*., 2003).

The necessity of this research is evident for the following reasons: umbrella palm as a fenny aquatic plant might be used for wastewater treatment in wetland method; data in this regard are not enough; necessity of applying treatment using natural methods with the lowest cost possible. So this research was necessary to obtain data regarding wastewater treatment by wetland. On the other hand, this study aimed to identify removal efficiency of chemical and microbial agents by umbrella palm; then compared it with reed's one in removal of these pollutants in Yazd, Iran.

MATERIALS AND METHODS

This is an applied-interventional study in which the efficiency of two plants including *Cyperus alternifolius* and *Phragmites australis* was studied in sub-surface constructed wetland method to remove following parameters: BOD_5, COD, TSS, NO_3-N, NH_3-N, PO_4-N, Total Coliform (TC) and Fecal Coliform(FC). It should be noted that control parameters including pH and temperature were measured too. At first, three reactors were built as pilot by method of Constructed Wetland with sub-surface flow and four retention days. Pilots' dimensions were as the following: 2 m length, 1.5 m width and 60 cm depth. In the two reactors, 50 seedlings of *Cyperus alternifolius* and *Phragmites australis* which were grown up to 15 days were planted and one pilot was considered as a control with no plant grown in. Soil gradation of all three reactors' bed was sand in which three different diameters of this soil was used so that sands with coarse size (10-25 mm) were located near reactor's outlet valve at the bottom, sands with medium size (8-14 mm) and small size (1-4 mm) were located in the middle and on top of the reactor respectively. Some clay was also added to the reactors in order to create an appropriate environment for growth of plants' roots. The wastewater which was used in this research was effluent of septic tank (as pretreatment). Input flow of each one of these wetlands was set to 20 L min^{-1}. Sampling was done 20 days after beginning of wetland operation with four retention days in summer season. Ninety samples were collected in two months period, i.e. in each step of sampling, 6 samples from input and output were collected using special containers. Samples were kept in ice in order to avoid their adverse reactions; then they were immediately transferred to the laboratory and tested according to standardized methods. After various tests, obtained results were analyzed by SPSS software and Paired Sample Test statistical analysis.

RESULTS

Average concentration of influent and effluent parameters including BOD_5, COD, TSS, NO_3-N, NH_3-N, PO_4-N, TC and FC in Constructed Wetland is shown in Table 1. The data indicated the average concentrations of BOD_5, COD and TSS in the influent of wetlands to be 197, 413 and 111 mg L^{-1}, respectively. There was the lowest amount of these parameters in the effluent of *Cyperus alternifolius* wetland, that is, regarding BOD_5, COD and TSS, they were 53, 104 and 17 mg L^{-1}, respectively (Table 1). Also the highest removal efficiency for BOD_5, COD and TSS turned out to be 73, 74 and 84% , respectively (Fig. 1). Average concentration of

Table 1: Average concentration of influent and effluent parameters in constructed Wetlands

Parameters	Ave. Influent	Ave. Effluent in control wetland	Ave. Effluent in *Cyperus alternifolius* Wetland	Ave. Effluent in *Phragmites australis* wetland
COD (mg L^{-1})	413	229	104	169
BOD_5 (mg L^{-1})	197	129	53	89
TSS (mg L^{-1})	111	25	17	29
NO_3-N (mg L^{-1})	9.1	7.7	5.4	8.5
NH_3-N (mg L^{-1})	59.5	59.3	37.6	57.6
PO_4-P (mg L^{-1})	7.4	7.3	4.9	6.6
Total coliform (MPN 100 mL^{-1})	2.8×10^6	2.3×10^6	8.4×10^5	1.8×10^5
Fecal.Coliform (MPN 100 mL^{-1})	2.6×10^5	1.9×10^5	1.6×10^5	1.3×10^5
pH	7.7	7.5	7.4	7.5
T (°C)	30.1	30.2	30.1	30

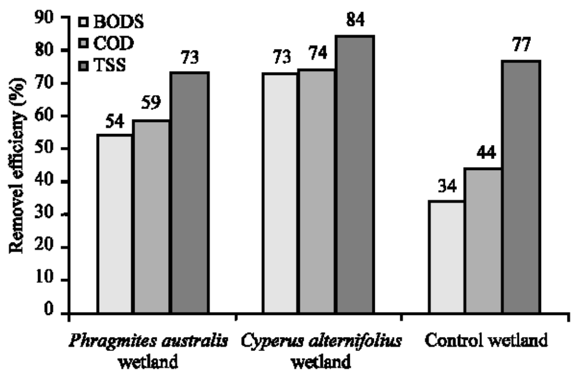

Fig. 1: Removal Efficiency (%) of BOD_5, COD and TSS in constructed Wetlands

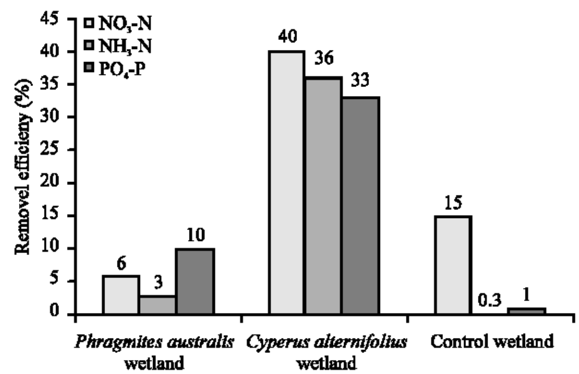

Fig. 2: Removal efficiency of NO_3-N, NH_3-N, PO_4-P in constructed Wetlands

NO_3-N, NH_3-N and PO_4-N in the influent of wetlands was shown to be 9.1, 59.5 and 7.4 mg L^{-1}, respectively. There was the lowest amount of these parameters in the effluent of *Cyperus alternifolius* wetland so that for NO_3-N, NH_3-N and PO_4-N they were 5.7, 37.6 and 4.9 mg L^{-1}, respectively (Table 1). Thus the highest removal efficiency in terms of NO_3-N, NH_3-N and PO_4-N reached 40, 36 and 33%, respectively (Fig. 2). Average concentration of TC and FC in the influent of wetlands stood at 2.8×10^6 and 2.6×10^5 MPN 100 mL^{-1}, respectively. There was the lowest amount of these parameters in the effluent of *Phragmites australis* wetland, that is, TC and FC turned out to be 1.8×10^5 and 1.3×10^5 MPN 100 mL^{-1}, respectively (Table 1). Therefore the highest removal efficiency in terms of TC and FC reached 93 and 50% (Fig. 3), respectively. The data represented that average of temperature and pH in the influent and effluent of all three CW was almost the same and was between 30-30.2 c and 7.4-7.7, respectively (Table 1).

Statistical analysis: demonstrated that reduction rate of the parameters including BOD_5, COD, TSS, NO_3-N, NH_3-N,PO_4-N and TC in all three CW was significant (p = 0.05). The reduction rate of FC, however, was not significant (p = 0.05).

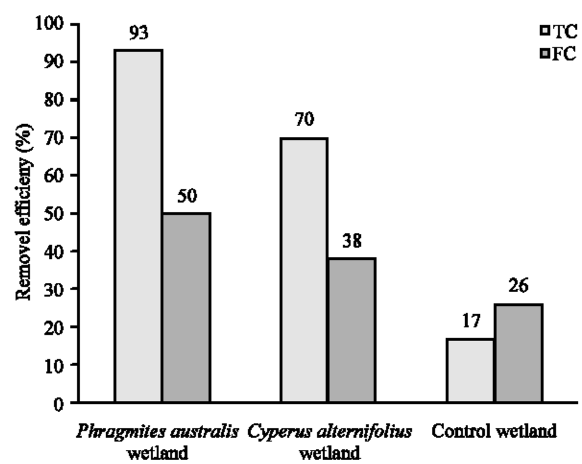

Fig. 3: Removal efficiency of TC and FC in constructed Wetlands

DISCUSSION

Results of this study indicated that wetland with *Cyperus alternifolius* plant had higher efficiency compared to *Phragmites australis* in removal of chemical parameters including NH_3-N ,NO_3-N ,TSS, COD ,BOD_5, PO_4-P. Moreover, results of this study identified that

Phragmites australis wetland had higher efficiency compared to wetland of *Cyperus alternifolius* in the removal of microbial parameters including total coliform and fecal coliform. Knight *et al*. (2000) performed a study on animal wastewater treatment using Constructed Wetlands. Results of this study showed that removal rate of parameters including BOD_5, SS, NH_4-N, TN and TP were 65, 53, 48, 42 and 42%, respectively (Knight *et al*., 2000). Liao *et al*. (2003) did another research on capability of *Cyperus alternifolius* and vetiver to treat pig field wastewater in China. Results of this study demonstrated that these two plant species removed COD, BOD_5, TP and NH_3-N parameters up to 64, 68, 18 and 20%, respectively in four retention days (Liao *et al*., 2003). Results of another research which was carried out by Song *et al*. (2006) indicated that using Constructed Wetland for wastewater removal could remove COD, BOD_5 and TSS up to 62.2%, 70.4%9 and 71.8% respectively (Song *et al*., 2006). Juang *et al*. (2008) in a research on pollutants treated by Constructed Wetland identified the average of BOD_5, SS and NH_3 to be 71.8, 36.6 and 41.7%, respectively. In this constructed wetland, a variety of plants such as *Cyperus alternifolius* were used. Retention time was specified 3-4 days (Juang *et al*., 2008). El-Khateeb *et al*. (2009) conducted a study in which Constructed Wetland with sub-surface flow was used for final wastewater treatment after one anaerobic process; the removal rate of BOD_5, COD and TSS with Constructed Wetland turned out to be 53, 66.6 and 68.2%, respectively (El-Khateeb *et al*., 2009). Comparison of the above-mentioned results with results of this study demonstrated that removal efficiency of chemical parameters was higher in this study. This increase may be the result of using *Cyperus alternifolius* plant. Thus, application of *Cyperus alternifolius* plant instead of *Phragmites australis* plant in wetland may be an appropriate alternative. Kadlec *et al*. (2010) performed a study on Constructed Wetlands with *Phragmites australis* plant in Columbia. Results of this study showed that the wetlands under study removed 98% of fecal coliforms and 95% of *E. coli*. Moreover, these wetlands had an effective role in removal of chemical agents (Kadlec *et al*., 2010). Results obtained from this study are parallel to above-mentioned study. This indicates that *Phragmites australis* wetland has higher efficiency in removal of microbial parameters compared to *Cyperus alternifolius*. Yang *et al*. (2006) conducted a research on a Constructed Wetland in northern China. Results specified that wetland can remove efficiently heavy metals from industrial wastewater in long-term application. Furthermore, it has removed more than 98% of suspended solids (Yang *et al*., 2006). Vymazal (2009) performed a study showing that application of Constructed Wetlands was effective in industrial wastewater treatment as well as waste leachate treatment (Vymazal, 2009). In view of similar studies and the results obtained from this study in representing high efficiency of *Cyperus alternifolius* wetland in removal of chemical parameters, it is clear that Constructed Wetland with *Cyperus alternifolius* plant can be used not only for Municipal wastewater treatment, but also for industrial wastewater treatment and waste leachate treatment. The results, moreover, indicated that *Cyperus alternifolius* has appropriate efficiency for removal of nutrients including nitrogen and phosphorus. Thus, this plant can be used for treatment of water and wastewater polluted by nutrient such as nitrate and phosphate (Stearman *et al*., 2012).

CONCLUSION

In general, this research detected that *Cyperus alternifolius* plant has acceptable efficiency for treatment of Municipal wastewater. Moreover, using a combination of *Phragmites australis* and *Cyperus alternifolius* wetland may lead to high efficiency of removal of chemical and microbial parameters. Of course, it is essential to perform additional studies on efficiency of these two plants in removal of nutrients, heavy metals, parasites' semen and intestinal viruses. Furthermore, capability of this plant in various climate conditions as well as industrial wastewater treatment with high organic loading should be investigated too.

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