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Full Length Research Paper

Phosphorus removal from aquaculture wastewater and latex by *Ceratophyllum demersum*

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Water pollution has always been a major problem in the environment. Polluted water is harmful for human health, thus, there is the need to clean water from polluting factors. One of the economical and rapid methods for removing elements is displacement of metals by biosorption. Three treatments in four replications for purifying wastewater by *Ceratophyllum demersum* were designed. The treatments included raw municipal wastewater (RMW), treated municipal wastewater (TMW), and diluted fresh latex (DFL). The experiment was performed in the open air of Khorasgan University area for 18 days "without aeration" and 18 days "with aeration" after the period of "without aeration". The results of the study indicated that the phosphorous (P) of TMW (4.48 to 0.53 meq/l), RMW (13.68 to 1.15 meq/l), and DFL (1.2 to 0.21 meq/L) was reduced in each of the treatments without aeration. In addition, the results also indicated that P of TMW (0.53 to 0.07 ds/m), RMW (1.15 to 0.39 ds/m), and DFL (0.21 to 0 meq/l) declined in the treatments with aeration. After this examination, the accumulation of phosphorous in *C. demersum* indicated that the phosphorous in TMW, RMW, and DCL without aeration increased by 63.67, 16.77 and 5.4% respectively. In another condition that was used with aeration, the results demonstrated the concentration of P in TMW, RMW and DFL treatments that was stored in *C. demersum* increased by 2.06, 34.19, and 48.59% respectively.

Key words: Pollution, *Ceratophyllum demersum*, phosphorous.

INTRODUCTION

During growing season, macrophytes accumulate nutrients from water (or both water and sediment). When the macrophytes die, the decomposition process begins. The release of nutrients raises the nutrient concentration in the water (Godshalk and Wetzel, 1978; Howard-Williams and Allanson, 1981; Godshalk and Barko, 1985), and the oxygen consumption lowers the dissolved oxygen level in the water and in the sediment (Pereira et al., 1994).Eutrophication is an important indication of serious water pollution (Gan and Guo, 2004). Phosphorus (P) is a key factor that causes eutrophication (Sas, 1989), because it enhances production in an amplified positive feedback (Furrer et al., 1996).

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Abbreviations: TMW, Treated municipal wastewater; **RMW,** raw municipal wastewater; **DFL,** diluted fresh latex.

Aquatic plants play a major role in the environmental conditions of stagnant and flowing waters. They produce organic matter and oxygen, and they provide food, shelter, and substrate for a variety of aquatic organisms. In addition, rooted macrophytes modify flow, stabilize sediments and promote retention of organic matter and nutrients (Cedergreen, 2004).

Submerged macrophytes can reduce the concentration of different P species in the overlying water, mainly by up taking the P from overlying water, however, aquatic vegetation, particularly submerged macrophytes, have declined and even disappeared from many lakes as a result of artificial eutrophication and irrational fishery management. Therefore, it was greatly needful to select submerged macrophytes that cannot only absorb the P greatly in lake water, but also control the release of P from the sediment (Tong et al., 2004; Huertas et al., 2006).

Ceratophyllum demersum (Coontail or hornwort) is a completely submersed plant and commonly seen in

Table 1. Preliminary tests run on the three treatments (TMW, RMW and DFL) at the beginning of the experiment in the two different conditions.

Parameter	Treatment in two condition		
	TMW_{wa}	RMW_{wa}	DFL_{wa}
TP (mg/l)	4.48	13.68	1.2
NH_4 (mg/l)	90	135	60
NO_3 (mg/l)	60	60	90
Ca (mg/l)	4.8	3.00	2.3
Mg (mg/l)	1.7	3.4	1.8
EC (ds/m)	1.34	2.68	1.2
COD (mg/l)	260	664	728
pH	8.14	6.28	5.85
	TMW_a	RMW_a	DFL_a
TP (mg/l)	0.53	1.15	0.21
NH_4 (mg/l)	16.66	29.16	16.11
NO_3 (mg/l)	26.19	27.5	25.55
Ca (mg/l)	1.31	1.7	1.32
Mg (mg/l)	1.2	1.65	0.85
EC (ds/m)	1.14	2.3	0.83
COD (mg/l)	64.5	152.75	189.5
pH	7.83	7.9	7.52

TP = Total phosphorus, NH_4 = Ammonium nitrogen, NO_3 = Nitrate nitrogen, Ca = Calcium, Mg = Magnesium, COD = Chemical oxygen demand, EC = Electrical Conductivity, $_{wa}$ = Without aeration, a = Aeration. TMW, Treated municipal wastewater; RMW, raw municipal wastewater; DFL, diluted fresh latex.

ponds, lakes, ditches, and quiet streams with moderate to high nutrient levels (Johnson et al., 1995). It does not produce roots, instead it absorbs all the nutrients it requires from the surrounding water. If it is growing near the lake bottom, it will form modified leaves, which it uses to anchor to the sediment. However, it can float freely in the water column and sometimes forms dense mats just below the surface.

Previous studies have also shown that *C. demersum* has high tolerance to freeze damage (Tone et al., 2004), and has strong ability to inhibit algal growth by releasing allelochemicals (Nakai et al., 1999). The foregoing advantages of *C. demersum* may enable it to be used as the pioneering species for the restoration of aquatic macrophytes in heavily polluted areas of shallow lake in future.

The main purpose of this study was to evaluate the role of *C. demersum* in removing phosphorous from waste-water and diluted fresh latex in order to establish the role of this plant in improving water quality.

MATERIALS AND METHODS

The aquatic plant (*C. demersum*) was collected from Zayanderood River (Isfahan, Iran) in spring season. Samples were thoroughly washed with tap water to remove any soil/sediment particles attached to the plant surfaces. Preliminary tests were run on the three treatments (TMW, RMW and DFL) at the beginning of the experiment in the two different conditions (Table 1). Twelve clear culture buckets were used to establish three treatments with four replications. The microcosm experiment was conducted from May 11, 2009 to June 5, 2009. The three treatments included three monocultures raw municipal wastewater (RMW), treated municipal wastewater (TMW) and diluted fresh latex (DFL). Each bucket was filled with 6 L of each treatment. Each microcosm was planted with 100 g (fresh weight) of *C. demersum.* This study was done at a temperature between 28 and 32°C. However, the temperature of treatment under which the plants were kept was between 24 and 26°C. The experiment was performed in the open air of Khorasgan University area under natural daylight for 18 days “without aeration” and 18 days “with aeration” after the period of “without aeration”. Losses in culture volume due to evapotranspiration were countered by the addition of distilled water to the original level every other day. *C. demersum* was harvested for each treatment after 18 days without aeration and after 18 days with aeration. Harvested plants were thoroughly washed in distilled water and oven dried at 80°C. Dried plant material was powdered and wet digested in HNO_3:$HClO_4$ (3:1, v/v) at 70°C.

The concentrations of P were measured according to standard methods (Yu, 2002). These concentrations of P were accomplished with spectrophotometer device.

All of the data collected during this experiment were analyzed with Statistical Package for the Social Sciences SPSS software (version 16.0) and were compared with the Duncan’s multiple range tests.

RESULTS AND DISCUSSION

The analysis of P from the three treatments (RMW, TMW and DFL) showed that *C. demersum* can effectively

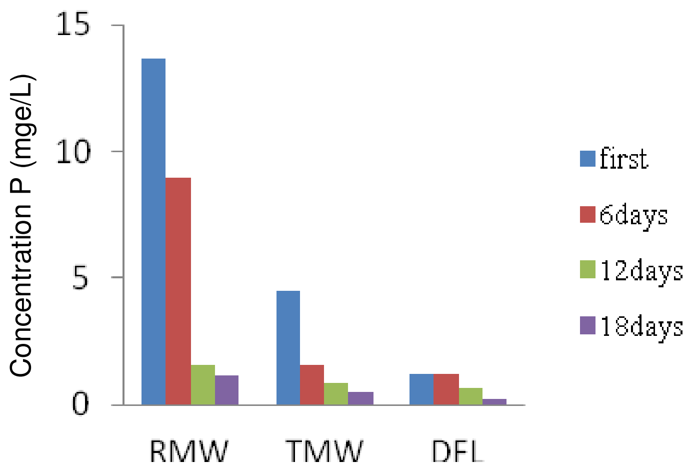

Figure 1. Removal of Phosphorus from three treatments (RMW, TMW and DFL) without aeration condition.

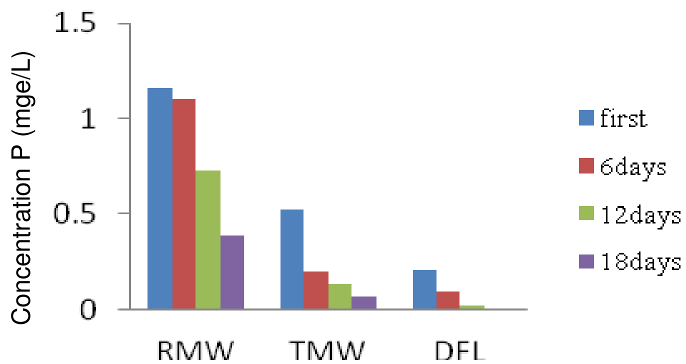

Figure 2. Removal of Phosphorus from three treatments (RMW, TMW and DFL) with aeration condition.

reduce P in two conditions, without aeration condition (Figure 1) and with aeration condition (Figure 2).

The concentration of P in all of the treatments without aeration indicated that *C. demersum* decreased P from 13.68 to 1.15 meq/l in the RMW treatment and decreased P from 4.48 to 0.53 meq/l in TMW treatment. In addition, this aquatic plant decreased the concentration of P in the diluted fresh latex (DFL) treatment from 1.2 to 0.21 meq/l for each of the three periods of six days.

C. demersum has a strong capability for anti-pollution; the biomass will increase and gradually become one of the dominant species in eutrophic lake (Rai et al., 1995; Wang et al., 2005). The foregoing advantages of *C. demersum* may enable it to be used as the pioneering species for the restoration of aquatic macrophytes in heavily polluted areas of shallow lake in future (Gao et al., 2009).

Investigating P concentration in aeration conditions demonstrated that *C. demersum* decreased the concentration of P in each of these treatments: TMW (from 0.53 to 0.07 ds/m), RMW (from 1.15 to 0.39 ds/m) and DFL (from 0.21 to 0.00 meq/l). *C. demersum*, a rootless aquatic plant, has forked leaves and thin cuticle on the plant surface. All these features facilitate up taking of metals from aquatic bodies through its large surface area with no complication of root-shoot metal partitioning. These features thus contributed to the adequate P accumulation observed in this study.Submerged macrophytes could be used in reducing the P levels of nutrient enriched waters (Gao et al., 2009). Mjelde and Faafeng (1997) showed that *C. demersum* development in shallow lakes had high phosphorous load. The concentration of P that was accumulated by *C. demersum* is shown in Figures 3 and 4.The concentration of P which was absorbed by *C. demersum* increased by 63.67, 16.77, and 5.4% in TMW, RMW and DCL treatments respectively after 18 days without aeration (Figure 3).

In addition, the percentage of P which was absorbed by *C. demersum* in aeration condition was increased by 2.0634.19, and 48.59% in TMW, RMW and DFL

Figure 3. The concentration of Phosphorus absorbed by *C. demersum* after 18 days without aeration condition.

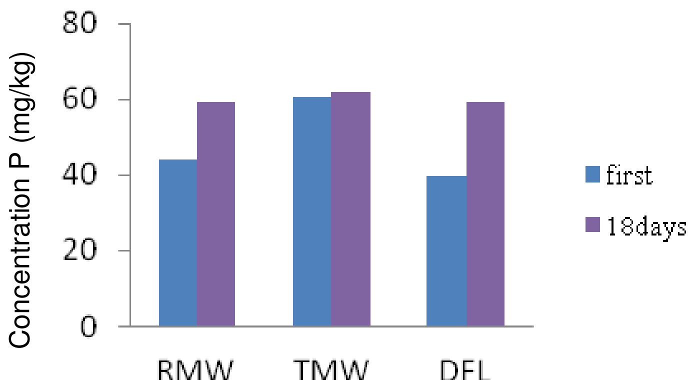

Figure 4. The concentration of Phosphorus absorbed by *C. demersum* after 18 days with aeration condition.

treatments respectively (Figure 4).

The results show that *C. demersum* can absorb high concentrations of P from wastewater. *C. demersum* had the best P removal effect with the removal rates of 91.75 and 92.44% respectively in the spring and autumn (Gao et al., 2009).

Mjelde and Faafeng (1997) showed that submerged macrophytes can reduce the concentration of different P species in the overlying water, mainly by up taking the P from the overlying water. However, aquatic vegetation, particularly submerged macrophytes, have declined, and even disappeared from many lakes because of artificial eutrophication and irrational fishery management (Tong et al., 2004).

Conclusion

This study shows that P was removed from RMW, TMW, and DFL by *C. demersum*. The experiment showed that submerged macrophytes such as *C. demersum* could be used in reducing the P levels of nutrient enriched waters. Among the submerged macrophytes*, C. demersum* could play a major role in the environmental conditions of stagnant and flowing waters.

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