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Performance of Duckweed (*Lemna minor*) on different types of wastewater treatment

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Abstract
The study was conducted to analyze the nutrient removal efficiency of duckweed (*Lemna minor*) on the different wastewaters such as municipal wastewater, sewage water and seafood processing plant wastewater. The experiment was conducted at four different dilutions such as raw water, 25%, 50% and 75% dilutions. In each experimental set up, duck weed was inoculated at the rate of 0.6 kg wet wt. /m2.The water quality parameters were analyzed once in a week. The maximum removal efficiency of 96% NH_3-N was observed in 25% dilution of all the three wastewaters. *Lemna minor* achieved the maximum removal efficiency of NH_3, NO_2, NO_3, PO_4, BOD and COD in municipal wastewaters at the rate of 96%, 98%, 98%, 96%, 79% and 79% respectively. This result clearly explains that duckweed is an alternative cost effective natural biological tool in wastewater treatment. This treated wastewater can be used for agriculture and aquaculture activities.

Keywords: hardness**,** alkalinity, wastewater, nutrient removal, eutrophication,

1. Introduction

Nutrient rich effluents when discharged into water bodies causes eutrophication, leading to algal blooms, which dies and depletes oxygen and make the water unfit for beneficial use. Production of aquatic plants to recover nutrients from the wastewater is an alternative technology to convert the nutrients into potentially useful products and prevent nutrient pollution of the environment (Cheng *et al.*, 2002) [3]. Various duckweed species have been used for the treatment of municipal and industrial wastewaters in many countries, including Bangladesh, Israel, and the U.S (Culley *et al.*, 1981; Oron, 1994) [11, 21]. Several investigators have assessed the performance of duckweed in removing ammonia from domestic wastewater and its assimilation into N compounds (Oron *et al.*, 1987) [22]. Duckweed wastewater treatment systems have been studied for dairy wastewaters (Culley *et al.*, 1981) [11], raw and diluted domestic sewage (Skillicorn *et al.*, 1993; Oron, 1994; Hammoudo *et al.*, 1995) [5,21,13], secondary effluents (Harvey and Fox, 1973; Sutton and Ornes, 1975) [14, 6], waste stabilization ponds (Wolverton, 1979) [9]. And fish culture systems (Porath and Pollack, 1982) [25]. Duckweed utilize these nutrients and produce large amount of biomass which can be used for some beneficial purposes. EL-Kheiret *et al.* (2007) [12]. reported that duckweed (*L.gibba*) was found to be very effective in the removal of nutrients, soluble salts, organic matter, heavy metals and in eliminating suspended solids, algal abundance and feacal coliform densities. Hence, the present study is designed to analyze the nutrient removal capacity of the *Lemna minor* on different wastewater treatment.

2. Materials and Methods

The experiment was conducted in three different types of wastewaters such as municipal wastewater (W_1), sewage water (W_2) and seafood processing plant wastewaters (W_3). The municipal wastewater was collected from a drainage channel nearby Arul Raj Hospital, Thoothukudi. The sewage water was collected from Therespuram, Buckal canal, Thoothukudi and seafood processing plant wastewater was collected from Ninan's seafood processing plant, Thoothukudi.

This experiment was carried out in 50 l plastic containers. The different wastewaters such as W_1, W_2 and W_3 were introduced in different plastic containers at four different dilutions such as raw wastewater (D_0), 25% dilution (D_1), 50% dilution (D_2) and 75% dilution (D_3). The initial water quality parameters (pH, dissolved oxygen, alkalinity, hardness, TDS, turbidity, ammonia, nitrite, nitrate, phosphate, BOD and COD) were analyzed.

The duckweed (*L. minor*) was inoculated in each experimental tub at a rate of 0.6kg wet wt. /m^2 to study the nutrient removal efficiency in different wastewaters. The experiment was carried out under sunlight for one month period. The water quality parameters were analyzed once in a week in each experimental set up. After one month period of experiment, the final water quality parameters were analyzed. The nutrient removal rates were calculated and expressed as percentage. The collected data were subjected to ANOVA test following the bio statistical methods of Christensen (1996) [4].

3. Result and Discussion

The values of pH, DO, alkalinity, hardness, TDS, turbidity of different wastewater treated with *L. minor* are given in Figure-1. The pH of the raw municipal, sewage and seafood processing plant wastewaters are under slightly alkaline conditions. In this experiment, the pH and DO values were gradually increased in all dilutions.

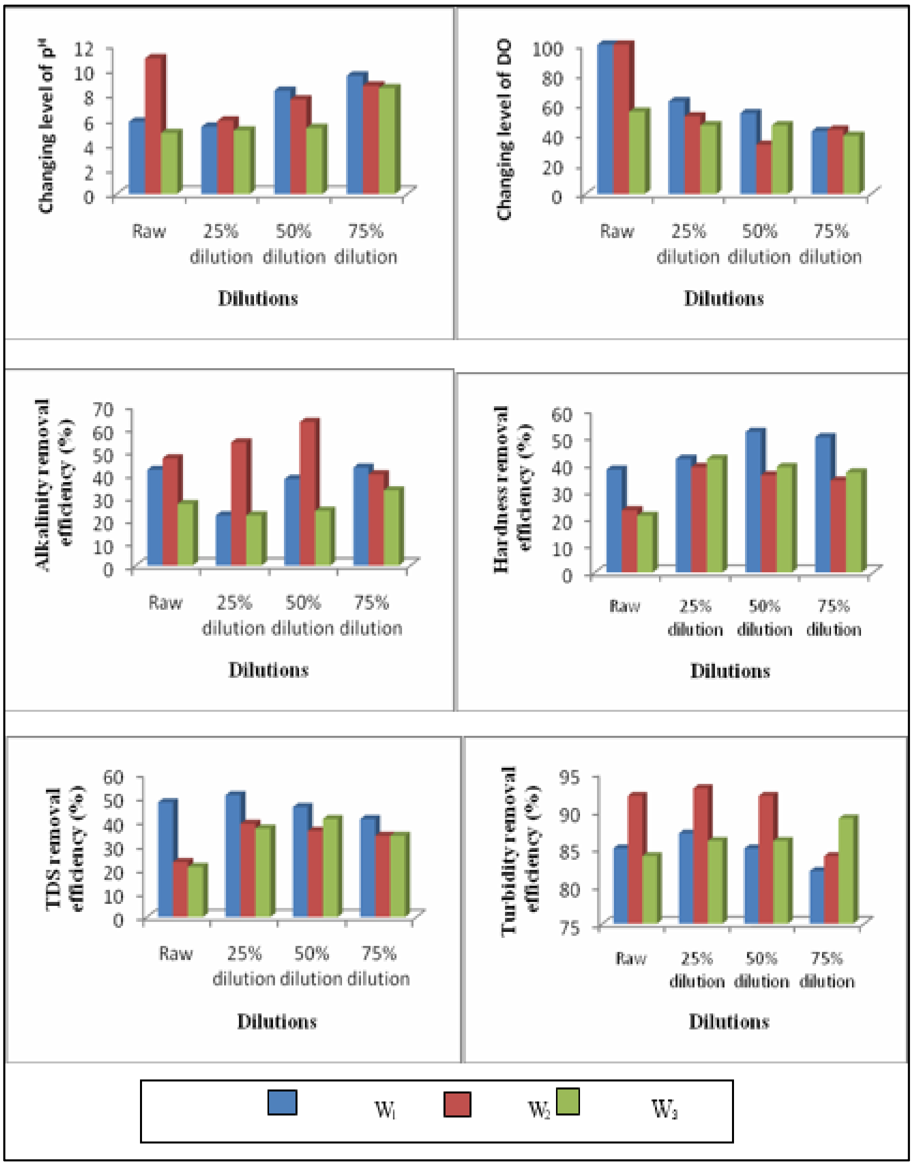

Fig 1: Change in pH and DO values and the reduction of total alkalinity, total hardness, TDS, turbidity values in duck weed (*Lemna minor)* treated different wastewaters

The maximum of 12% increase in pH was noticed in W_2D_1. Ozengin and Elamari (2007) [23] and Bal Krishna and Polprasert (2008) [1] also reported the increase in pH values in duckweed based wastewater treatment system. The increase in pH in all the treatments might be due to the photosynthetic activity of the algae which utilized CO_2 and produced less amount of carbonic acid. In raw sewage water, the maximum of 99% of increasing level of DO was noticed. Confirming our results, EL-Kheir, *et al.* (2007) [12] also reported the gradual increase in dissolved oxygen level in sewage wastewater treated with duckweed (*L. gibba*). The increasing level of DO may be due to the production of gaseous oxygen which was caused by the photosynthetic activity of algae.The values of ammonia, nitrite, nitrate, phosphate, BOD and COD of different wastewater treated with *L. minor* are given in Figure-2. Among the different wastewaters, the maximum of 63% alkalinity reduction was observed in W_2D_2 and minimum of 22% reduction was observed in W_1D_1. EL-Kheir *et al.* (2007)[12] reported the reduction in alkalinity values from 268.60 to 239.40 mg/l on 6th day and increased after 8th day up to 308.70 mg/l in sewage water treated with *L. minor*. The hardness removal rate was found highest in W_1D_2 and lowest in W_2D_O and the values are 52% and 21% respectively.

Among the different wastewaters, the TDS reduction was found higher in W_1D_1 at the rate of 51% and lower in W_3D_O at the rate of 21%. The higher rate of removal observed might be due to

the removal of salt contents. The maximum turbidity removal of 93% was noticed in W_2D_1.Duckweed reduced the turbidity level by the adsorption of colloidal materials. Center *et al*., 2002 [2] also suggested that all the plant matter reduced the turbidity by adsorption of colloidal materials. In the present study, the significant difference was noticed between different dilutions and different water quality parameters such as dissolved oxygen, total alkalinity, total hardness
And TDS ($P < 0.05$)

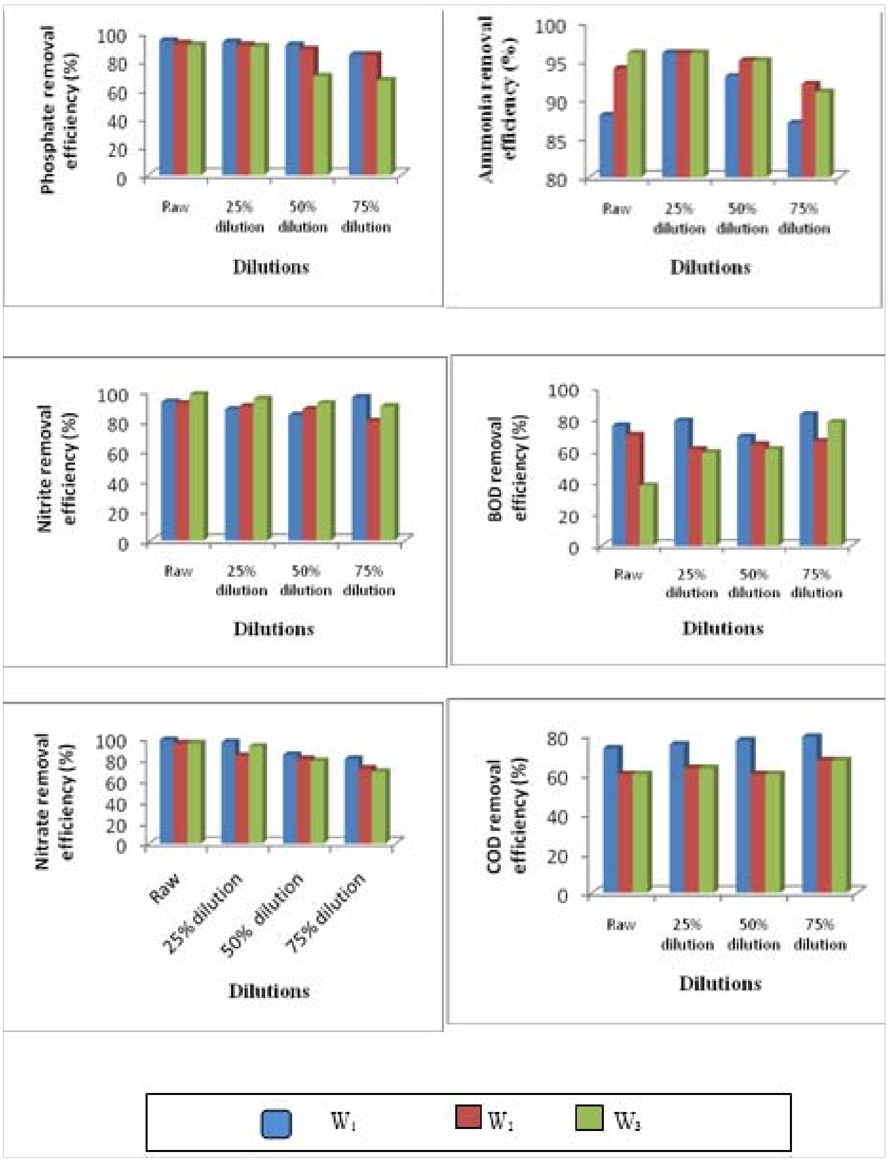

Fig 2: Ammonia, nitrite, nitrate, phosphate, BOD and COD removal efficiencies of duckweed (*Lemna minor*) in different wastewater treatment

In the present study, the maximum of 96% of ammonia removal was noticed in 25% dilution in all the three wastewaters (W1, W2 and W3). The ammonia and NO_3 removal efficiency showed a significant difference between dilutions ($P<0.05$). Rogers *et al.* (1991) [26] concluded that the dominant removal mechanism for nitrogen is by plant uptake. Nitrification – Denitrification complex has been established as the major removal mechanism for nitrogen. EL-Kheir *et al.* (2007) [12] reported that *L. gibba* removed 80% of ammonia in municipal and sewage wastewater. This also agrees with our present study. The rapid reduction of ammonia nitrogen in the present study is the result of active nitrification as evidenced by an increase in NO_3 concentration in water. Kutty *et al.* (2009) [18] reported the maximum removal of 98% ammonia in municipal wastewater.

Among the different wastewaters, the maximum of 99% nitrite removal was observed in 50% diluted seafood processing plant wastewater. All plants first prefer ammonia and then nitrate as a nutrient nitrite is an intermediate product. The oxidation of ammonia to nitrite could not be explained in the light of the available literature. In our present experiment, the maximum of 99% nitrate removal was observed in 75% diluted sewage water and minimum of 66% removal in 50% diluted seafood processing plant wastewater. The reduction of Nitrate- nitrogen in different wastewaters agree with those reported previously by Matusiak *et al.* (1976) [19] and Tam and Wong (1989), they suggested that algae preferentially utilize ammonium and other reduced forms of nitrogen, leaving nitrite and nitrate in wastewater. Macro algae require phosphorus as an essential element for growth. Algae are proposed to remove the phosphorus compounds and contribute in the wastewater treatment. Among the *Lemna* treated wastewaters, the phosphate removal rate was found higher in W_1D_1 at a rate of 96% and lower in W_3D_O at a rate of 65% reduction. Removal efficiency of 14.0 to 92.2% phosphorus in wastewater system using *L. gibba* was reported by Korner and Vermaat (1988) [16]. Vermaat and Hanif (1998) [8] reported that experimental study of domestic wastewater with Lemnaceae resulted in 77% removal of total phosphorus. Phosphorus removal in our system is due to plant uptake, microbial immobilization into detritus plant tissue, retention by underlying sediments and precipitation in the water column.

In the present study, the maximum BOD removal efficiency was noticed in W_1D_1 at the rate of 79% and minimum in W_3D_O at the rate of 38% reduction. Confirming this result, Pandey (2001) [24] reported 66 – 80 % reduction of BOD in duckweed ponds. Kuraishi and Sharma (2010) [17] reported 85.4 to 87.3% of BOD reduction in raw domestic sewage over 28 day retention time. Zimmo *et al*. (2003) [10] found that BOD removal efficiency was higher in duckweed based ponds than in algal based ponds. Korner *et al.* (1998) [16] mentioned that duckweed significantly enhanced the COD removal in shallow water. Pandey (2001) [24] reported the COD removal at the range of 70- 80% in the duckweed treatment system. Similarly, in our study, the COD level gradually reduced from 320 to 85 mg/l (73 % removal) on 28th day in W_1D_O. The COD removal efficiency showed that there is significant difference between various dilutions and different wastewaters ($P < 0.01$).Aquatic plants have a unique feature of transporting oxygen through leaves, stem and roots. Oxygen thus transported can enter water column and subsequently utilized by the bacteria on duckweed is more effective as duckweed roots and lower frond surfaces provide oxygen at a ‘micro-site level’ within the biofilm (Korner *et al.*, 1998) [16].Hence, duckweed is found to be more effective in organic load removal as it provides additional surface for bacterial growth and additional oxygen supply.

4. Conclusion

Among the three different wastewaters, *Lemna minor* achieved the maximum removal efficiency of NH_3, NO_2, NO_3, PO_4, BOD and COD in municipal wastewaters at the rate of 96%, 98%, 98%, 96%, 79% and 79% respectively. The present research work concludes that *Lemna minor* can perform well in municipal wastewater when compared to sewage and sea food processing plant wastewater treatment systems. Through this investigation, it could be concluded that the nutrient removal load in wastewater can be reduced through duck weed and thus eutrophication could be avoided. There by it is also possible to improve the quality of different wastewaters. The treated wastewater can be used for agriculture and aquaculture activities. The nutrients wasted through wastewaters could be used to produce *Lemna* biomass and the same could be used as feed for livestock or production of fuel. This wastewater grown duck weed can replace upto 30% of the diet of blue Tilapia (*Oreochromis niloticus*).

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