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A Study on the Removal of Pollutants from Wastewater by Aquatic Macrophytes

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수생식물에 의한 폐수의 오염물질제거에 관한 연구

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Abstract Macrophyte plays an important role in purification of wastewater. They have capacity to improve the water quality by absorbing nutrients, with their effective root system. In this study, removal of nutrient as well as organic matter was observed by some important macrophytes i.e. *Pistia stratoites*, *Hydrocharis dubia* and *Salvinia* sp. independently as well as in mixed culture under the laboratory condition. The highest total nitrogen removal was observed for *Pistia stratoites* (86.47%) in monoculture and *Salvinia* sp. + *P. stratoites* (76.11%) in mixed culture system. Corresponding figures for total phosphorous were observed for *P. stratoites* (75.60%) in monoculture and *Salvinia* sp. + *P. stratoites* (71.11%) in mixed culture system. Similar result was observed for ammonia removal in both systems. Additionally, *P. stratoites* showed the highest removal of organic matter, in monoculture system (68.46%) where as *Salvinia* sp. + *P. stratoites* showed the highest removal of organic matter in mixed culture system (82.73 %).

요 약 수생식물은 폐수정화에 있어서 중요한 역할을 한다. 수생식물은 뿌리로 영양물질을 흡수해 수질개선을 할 수 있는 능력을 가지고 있다. 본 연구에서는 실험실에서 수생식물인 물상추, 자라풀, 생이가래를 각각의 수조와 혼합한 수조에서 영양물질 제거뿐만 아니라 유기물에 관해 관찰하였다. 단일수조에서 가장 많이 제거된 총 질소는 물상추가 86.47%이고, 생이가래와 물상추가 혼합 식재된 수조가 76.11%로 관찰되었다. 총인의 경우 단일수조에서 가장 많이 제거된 것은 물상추가 75.60%이고, 생이가래와 물상추가 식재된 수조가 71.11%로 관찰되었다. 암모니아제거의 경우도 두 개의 수조에서 유사한 결과가 나타났다. 또한 물상추 식재된 단일수조가 유기물이 가장 많은 68.46%로 제거를 보였다. 반면 혼합수조에서는 유기물의 제거가 생이가래와 물상추가 식재된 수조가 가장 많은 82.73%로 나타났다.

Key words : Aquatic macrophytes, Monoculture, Mixed culture, Nutrient removal.

1. Introduction

The high productivity and pollutant removal capability of aquatic plants in wastewater treatment is well known[1]. Natural aquatic systems have created substantial interest regarding their potential use for wastewater treatment and resource recovery using green environments. Aquatic plant system has been accounted as one of the processes for wastewater recovery and recycling. The main purpose of using this system has focused on waste stabilization and nutrient removal. Plant assimilation of nutrients and its subsequent harvesting are other mechanisms for pollutant removal.

Macrophytic vegetation plays an important role in maintaining the ecosystem. Various types of macrophytes emergent, free, floating, submerged are generally observed

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in an aquatic ecosystem.

Free floating macrophytes in which leaves and roots are floating, roots are not attached in sediment. It has tremendous capacity of absorbing nutrients and other substances from the water[2] and hence brings the pollution load down. The macrophytes provide good conditions for physical filtration and a large surface area for attached microbial growth and activity[3]. Aquatic macrophytes can also utilize large amounts of N and P removal capacities of different aquatic plants [4,5]. The nitrogen and phosphorous are considered to be the major inorganic nutrient elements for the promotion of plant growth. Macrophytes also have a metabolic role in wastewater treatment with the potential to release O_2 into rhizosphere aiding in nitrification and by the direct uptake of nutrients[3, 6].

The major ecological function of wetlands includes water purification, hydrological modification, protection against erosion and deposition, provide habitat for flora and fauna, aesthetic appeal and provide recreational opportunities[7]. The wetland system is energetically sustainable because it uses only natural energy to reduce pollutants. They not only assimilate pollutants directly into their tissues, but also act as catalysts for purification reactions by increasing the environmental diversity in the rhizosphere, promoting a variety of chemical and biochemical reactions that enhance purification[8]. Therefore, the use of wetland technologies is increasingly employed for wastewater treatment because of its positive greenhouse results, also its being relatively cost and efficient. Wetland plants play a wide range of roles in constructed wetlands for wastewater treatment. Roles includes the physical effects of the plants themselves in sedimentation, erosion control and providing surface area for microbial growth(Bioflims), thus increasing microbial assisted processes including nitrification and denitrification. The objective of the current study was to compare the potential of three floating aquatic macrophytes in monoculture and mixed culture system, in removing the total nitrogen, ammonium nitrogen, total phosphorous and organic matter from domestic wastewater and to establish their role in improving water quality.

Wastewater treatment in aquatic macrophytes system occurs by several mechanisms including solids settling, plant uptake of contaminants, biotransformation, and physico- chemical reactions. This paper compares the nutrient removal in mono and mixed culture system within the culture media for the selected floating aquatic macrophytes in laboratory condition on diluted domestic wastewater.

2. Experimental methods

Study was designed to evaluate the nutrient removal capacity of selected aquatic macrophytes such as *Pistia stratoites*, *Salvinia* sp. and *Hydrocharis dubia*. All the three plants were cultured individually (monoculture) with 100% cover and in combinations with equal coverage of the total surface area of aquarium by the two partners in mixed cultures[9]. Four sets of aquarium were set in laboratory having 20L of diluted wastewater; dilution was done by the addition of wastewater with tap water in a 1:1 ratio. The aquarium with no aquatic plants referred to as ‘control set’. Each aquarium was filled by 20L of diluted wastewater and losses in culture volume due to evapotranspiration was maintained by the addition of deionized water to the original level prior to the day of sampling so that deionized water additions would minimally impact measurements[10]. The experiment was conducted over a 1 month period, during which observations were made of changes in appearance and growth of the plants. Through out the study the growth chamber was adjusted 24℃ temperature, 60% humidity and alteration of photoperiod(12h light and 12h dark).

The treatments were evaluated by measuring the chemical parameters in grab samples. Samples were obtained by dipping a 100ml graduated beaker at the center of aquarium. Care was taken to minimize disturbance of the plants. The wastewater in each aquarium was sampled 9 times over a 32 day period, on days 0, 4, 8, 12, 16, 20, 24, 28, and 32. The parameters measured included chemical oxygen demand(CODcr), total nitrogen(T-N), ammonium nitrogen(NH_3-N), total phosphorous(T-P).

CODcr was determined by reactor digestion method with test kit. After mixing the kit was heated for 2 hour sat 150˚C in thermoreactor(model# WTW- CR-3200). The sample was cooled down for ten minutes and measured the CODcr value in portable spectrophotometer(model#

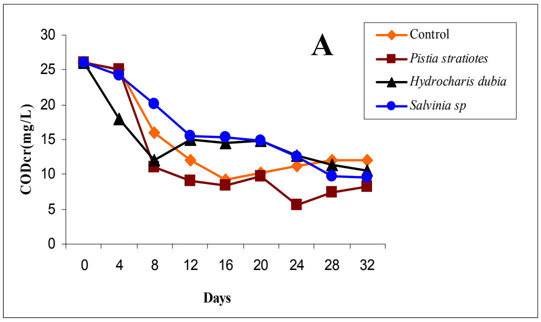
HACH-DR-2800) at 450nm. T-N was determined using the chromotropic acid method with test kit. The kits were shaked for 1-2minutes and heated for 30min at 120˚C in thermoreactor(model# WTW-CR-3200) and cooled down for 10minutes. The T-N was measured in portable spectrophotometer at 410nm(model# HACH-DR-2800). Ammonia was determined by Nessler Method by using test kits. For the ammonia test 1ml filtering sample was added in the test kit tube and added 4 drop of solution S1 and 1ml of solution S2. The test kits were shaked for 1-2 minutes and hold for 3minutes. The value was measured by(model# HACH-DR-2800) portable spectrophotometer at 450nm. T-P(filtered samples) was determined by Ascorbic Method with test kits. 5ml sample was put in test kit and powder P1 was added. The test kits were shaked for 1-2 minutes to dissolve powder. The kits having powder and sample were heated for 30min at 120˚C in (model# WTW-CR- 3200) thermoreacter. Test kits were hold for ten minutes at the room temperature and measured the removal of T-P value by (model# HACH-DR-2800) Portable spectrophotometer at 880nm.

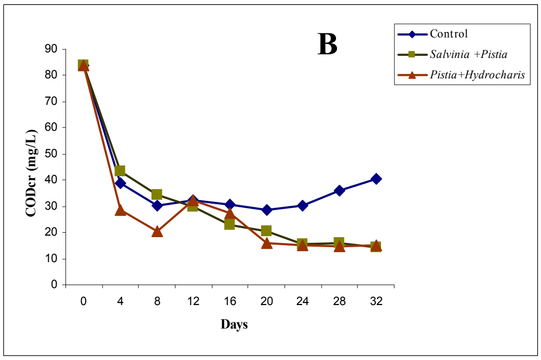
3. Results and discussion

3.1 Variation of chemical oxygen demand

Figure 1 A and B illustrated the changes of CODcr concentrations by considering the plant species and control experiment in monoculture and mixed culture systems. Initially the CODcr concentration of wastewater in monoculture was 52.00mg/L, where as in mixed culture it was observed for 84.00mg/L. After the treatment period of 32 days with *Pistia stratoites* showed 16.40 mg/L (86.66%) for the monoculture.

Similarly, in mixed culture system it was observed for the mixture of *Salvinia* + *Pistia*, 14.50mg/L (82.73%). Around 50% of the decrease in parameters occurred within the first 12 days of the experiment. This reduction was mainly brought about by sedimentation in the control system and additionally by filtration through the root systems in the plant cultures. An important consequence of figure 1 A and B showed that the first two week is favorable to get optimum removal of CODcr. Result also showed that the plants were significantly more efficient compared with the control. In both of the system the rise of CODcr observed after two weeks. Our result confirmed that the growth of water lettuce (*Pistia stratoites*) individually and in mixed culture showed higher performance to remove CODcr mainly because of well developed root system which can hold the initially low level of CODcr. Similar result was observed by[11]. A major part of the degradation of pollutants in the wastewater is attributed to micro- organisms which may have established a symbiotic relationship with plants.





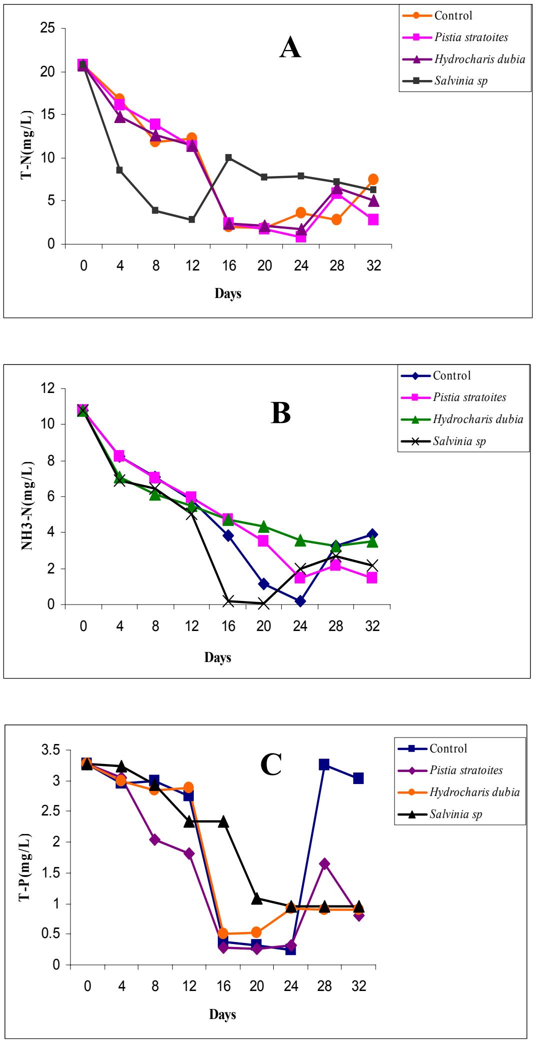
[Fig. 1] Variation of CODcr in control and planted experiment in monoculture [A] and mixed culture system [B].

3.2 Nutrient removal

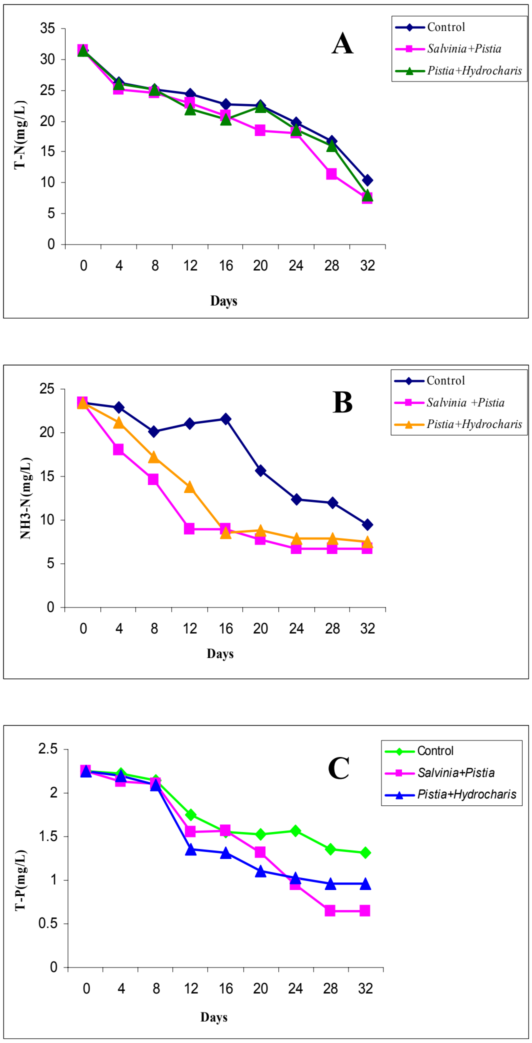
The losses of nitrogen and phosphorous concentrations were observed to have close relationship with different plant species. Planted treatment showed the removal of T-N compared with control treatment. These T-N removal rates were significantly greater than those for control treatment. Removal of N occurred by plant uptake, microbial assimilation and denitrification processes.

During present investigation the highest removal of T-N was recorded for *Pistia stratoites*(86.47%) in monoculture and the mixture of *Salvinia* + *Pistia* 76.11% was observed for mixed culture system. Physiology of plant such as height of plants and the shape of leaves also affected the overall nutrient in aquatic plant treatment[12]. In our experimental plants, the *Pistia stratoites* has the highest leaf area and biomass that is why in monoculture system *Pistia stratoites* and in mixed culture system *Pistia* + *Salvinia* showed the highest T-N removal as compared to other plant species. Removal of T-N also attributed by micro-organisms attach on the different parts of plant, they form a biofilm layer, which played an important role to removal nitrogen from wastewater[13]. This indicated that plant uptake is one of the major nutrients removal pathways. In addition to plant uptake, T-N removal can occur by NH_3 volatilization favored by high pH, nitrification under aerobic conditions and denitrification under anaerobic conditions and formation of organic films[14]. In the present study, T-N removal was occurred by volatilization because pH was higher than 7. Figure 2B and 3B showed the removal of ammonium nitrogen. In the monoculture system, *Pistia stratoites* was able to remove the ammonium nitrogen by 86.66% followed by *Salvinia* 79.62%. Similarly in mixed culture system, it was observed for the mixture of *Salvinia* + *Pistia* 71.28%. At the end of experiment the presence of plants significantly reduced the ammonium nitrogen from their initially low levels where as in the control the value was somewhat higher. It may be due to that in control system, nitrification probably did not occur due to the lack of support for the nitrifying bioflim to grow. In our experiment although, the diluted wastewater initially had low level of NH_3-N, the *Pistia stratoites* helped in further purification of water so we can consider this species to be a good water quality indicator.

Phosphorous is needed for plant growth and it's required for many metabolic reactions in plants and animals. Plants, algal and micro-organisms all utilize P as an essential nutrient and contain P in their tissue[15]. Figure 2C and 3C showed the removal of T-P in mono and mixed culture. In monoculture *Pistia stratoites* showed maximum removal of T-P by 75.60%, followed by *Hydrocharis dubia* 72.56% within a given time period. Similarly, in mixed culture, it was observed for the mixture of *Salvinia* + *Pistia*, 71.11%. In both of the cases plants are significantly more effective to remove the T-P as compared to the control experiment. Reduction of T-P may be due to uptake of soluble P, filtration of particulate matter through the roots, and settling. Although initial level of P was low but the plant like *Pistia stratoites* with a well developed root system further purify the diluted wastewater. Combinations of large leaf and small leaf aquatic macrophyte removed higher nitrogen and phosphorous.



[Fig. 2] Variation of T-N [A], NH_3-N [B] and T-P [C] in control and planted experiment in monoculture.



[Fig. 3] Variation of T-N [A], NH_3 [B] T-P [C] in control and planted experiment in mixed culture system.

4. Conclusions

Aquatic macrophytes showed the significant removal of nutrient as compared with control. Floating plant such as water lettuce (*Pistia stratoites*) showed the highest removal of nutrients (T-N and T-P) in monoculture. It may be due to well developed root system in *Pistia stratoites* which provide the good habitat for bacteria to enhance the nitrification and denitrification which result in higher N and P removal. Similarly, mixture of *Salvinia* + *Pistia* showed the highest removal of nutrient. Combination of large and small leaf aquatic macrophyte removed the higher nutrient. Therefore, *Pistia stratoites* and *Salvinia* combination may be more effective to remove the nutrient in diluted wastewater.

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<Research Interests >
Ecology, Environmental Impact Assessment