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Waste Water Management through Aquatic Macrophytes

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Abstract

Various wastewater treatment technologies are being used depending on various factors ranging from their availability, suitability and cost effectiveness to the local conditions. Many of the available technologies, although very effective are not used very frequently as they are cost intensive. Aquatic Macrophytes growing in and around water bodies have shown great potential in removal of pollutants. Many studies have been conducted in the past which reveal wastewater treatment potential of aquatic macrophytes. However, the studies in past mostly focused on a single species and were merely laboratory experiments that were conducted in stagnant waters of aquarium. The present study deals with assessment of treatment potential of two aquatic macrophytes grown in combination. The study also deals with online treatment of river Varuna water using combination of aquatic macrophytes. The results of the online study reveal that D. O. increased by 5.46%, B.O.D. decreased by 17.43%, C.O.D. decreased by 18.7%, Nitrate decreased by16.2% and Phosphate decreased by17.1%.

Keywords: Wastewater, treatment technologies, aquatic macrophytes.

Introduction

Most of the wastes generated, ultimately find their way into the water bodies i.e., rivers, ponds and lakes. The presence of these wastes in water bodies becomes undesirable, as it hinders the sustenance of life in a proper way. In recent years, scientific community all over the world has shown great concern over the deteriorating state of water bodies. Several techniques, all around the globe, have been developed to remove pollutants from the water bodies. Most of these techniques, though effective on one ground fell short on other grounds and moreover, they are too costly to be adopted in a feasible manner. Researchers are still in progress to search for technologies which could be employed to treat the wastewaters in feasible manner. Most of the modern technologies used to treat the wastewaters have their own implications, as these technologies are quite costly and energy intensive. So, most of the developing countries may not be able to afford the huge expenditure required to treat the wastewater by modern technologies. From the given fact it can be easily inferred that the developing world may either not be having access to modern wastewater treatment technologies or if at all they have those technologies then they may not be able to treat the entire wastewater generated there. In fact none of the countries of the world could claim to treat all the waste generated there through modern technologies.

In recent past, utilization of aquatic macrophytes for the wastewater treatment has been reported as an economical device for the treatment of wastewater. Several aquatic macrophytes growing naturally in polluted water have recently been used for the removal of pollutants as they consume them as nutrients[1-8]. Many research workers have studied the nitrogen and phosphorus removal capacity of different aquatic macrophytes[10-16]. Nitrogen uptake is the most obvious nitrogen retention mechanism involved. However, high removal efficiency through assimilative uptake by vegetation can only be achieved by frequent harvesting of fast growing plants[17]. Few workers have studied denitrification in epiphytic microbial communities[16,18].

In recent years much attention has been given on wastewater treatment with the help of aquaculture (growth of aquatic plants having economic values) and recycling of treated water. After treatment these aquatic plants are also utilized for energy regeneration[19], animal feed production[1,20], biogas production[21,22], as fibre[23], compost production for soil amendments[24] and source of protein[25] .

Most of the studies regarding the nitrogen and phosphorus removal capacity of aquatic macrophytes were restricted to one or a few plants. There is still paucity of data, on the comparative studies of removal of nitrogen and phosphorus of different plants in tropical freshwater systems, and nutrient removal capacity of plant combinations.

The aim of present investigation was to evaluate the pollutant removal capacity of water hyacinth and lesser duckweed, singly and in combinations and to evaluate the pollutant removal capacity of these plants in field and laboratory conditions.

Material and Methods

From literature it was noted that following two freshwater macrophytes reduce the pollutants from polluted water effectively.

Water hyacinth: The water hyacinth (*Eichhornia crassipes* (Mart.) Solms.), is a productive aquatic macrophyte which occurs as weed in most tropical and subtropical regions of the world. This is an angiospermic, large leaved, floating hydrophyte belonging to the family Ponterderaceae. This is a perennial noxious aquatic weed floating on water surface and partly rooted in shallow water with numerous fibrous roots, short stem, broad glossy green leaves and light lavender flowers. Vegetative reproduction is rapid and the water surface is soon covered by a dense mat.

Lemna minor: *Lemna minor* is an angiospermic, small leaved, free floating hydrophyte. It has a wider geographic range. It vegetates at above (1^0C-3^0C) reached to the maximum growth in December. Under laboratory condition at 27^0C it was reported to be double in area in four days only.

At Varanasi about 213 mld of sewage mixed with industrial effluents is being generated. Out of which about 95.2 mld of sewage is being discharged in the river Varuna. Under Ganga Action Plan, the sewage treatment plants have been established at Dinapur, Bhagwanpur and D.L.W. The sewage treatment plant at Dinapur, has the highest capacity of 100 mld while the capacities of plants at Bhagwanpur and D.L.W. are 12 and 10 mld respectively. The 95.2 mld of sewage discharged in river Varuna assumes significance, since, it is not being treated by any of the existing sewage treatment plants the only consolation is that 47 mld of it is pretreated. As a result, municipal sewage mixed with industrial effluents discharged in river Varuna reduces it to an open sewer, which pollutes the river Ganga when it drains into it.

River Varuna, the only tributary of Ganga at Varanasi (the other being river Assi, which has been reduced to a municipal drainage called Assi nala), has a significant role to play at Varanasi because the river water is being used for different purposes. Therefore, treatment of polluted Varuna water is being sought. In order to suggest ecomanagement practices and minimize water pollution level of river Varuna, some field as well as laboratory experiments were conducted.

Microcosm Investigation in Field: In order to evaluate the treatability of river Varuna water using aquatic macrophytes, an online field experiment was conducted in the month of May and June, 2000 because during the months of May and June the volume and velocity of river water was found highly and significantly reduced. During this study five gates of the Sampurnanand bridge (an overbridge on river Varuna) were closed in such a way that most of the river water was retained on upstream side of the bridge and only a part of the river water was allowed to pass to the downstream side of the bridge. After closing the gates, luxuriant growth of naturally growing aquatic macrophytes i.e., *Eichhornia crassipes* and *Lemna minor* was observed towards the upstream side of the bridge. These macrophytes multiplied rapidly and within a very short timespan, it was found that 1 km stretch of the river water was covered with these macrophytes. During the experiment DO, BOD, COD, NO_3-N and PO_4-P of the river water were analysed before and after the macrophytic zone regularly at alternate day for 20 days.

Laboratory experiments: The aquaculture laboratory experiments were performed to evaluate the pollutant removal efficiency of *E. crassipes* and *Lemna minor* from river water when grown singly and in combinations under laboratory conditions.

In order to compare the pollutant removal capacity of *E. crassipes* and *Lemna minor* in the field as well as laboratory conditions, the river water was collected from the region, where water quality was analysed during microcosm field investigation i.e. before the macrophytic zone. 100 litres of polluted river water, collected from the field, was poured in each of the 20 glass aquaria of 150 litre. Five replicates of the following experimental sets were used for the laboratory experiments.

Experimental set 1 - containing no aquatic plants (control), Experimental set 2 - containing 100% coverage of *E. crassipes,* Experimental set 3 - containing 100% coverage of *Lemna minor,* Experimental set 4 - containing 50% coverage of *E. crassipes* and 50% coverage of *Lemna minor.*

In order to compare the pollutant removal capacity of *E. crassipes* and *Lemna minor* in the field as well as in laboratory conditions, the water was collected from the zone where from water quality was analysed before macrophytic zone. 100 litres of river water collected from the field was poured in each of the 20 glass aquaria of 150 litre capacity which were used for laboratory experiments. Five replicates of each experimental set including control were kept in the laboratory. The plants used for aquaculture experiments were collected from Botanical Garden, Banaras Hindu University, Varanasi. The roots were thoroughly washed with the tap water, before the plants were introduced in the aquarium.

Table-1
Properties of River Varuna water during microcosm field investigation

Parameters	**Water quality before macrophytic zone (mg l^{-1})**	**Water quality after macrophytic zone (mg l^{-1})**	**Percentage increase (+) decrease (-)**
Dissolved oxygen	2.3	2.43	(+) 5.46
Biochemical oxygen demand	78	64.4	(-) 17.43
Chemical oxygen demand	132	107.31	(-) 18.7
Nitrate	0.93	0.779	(-) 16.2
Phosphate	1.48	1.226	(-) 17.1

* Average of 10 samples

Prior to the introduction of plants into aquaria initial concentrations of DO, BOD, COD, nitrate and phosphate of the river water sample used in all the aquaria were analysed. Aquaria water quality was also examined regularly at 7 days interval. Loss of water due to evaporation was maintained by the addition of distilled water. Since after 56 days, no significant removal of pollutants was noted so the experiment was stopped after 56 days. Some biochemical properties of plants such as crude protein, phosphate and nitrate were analysed at initial stage and after 56 days harvesting, using the standard methodology.

Results and Discussion

Data obtained during present laboratory experiments are shown in figures-1 to 5.

From the data obtained during the present investigation as represented in figure-1, it was revealed that Dissolved oxygen content decreased progressively in the experimental set containing 100% *Eichhornia crassipes*. Highest decrease i.e. 76.85±5.98% was noted in the experimental set containing 50% *Eichhornia crassipes* and 50% *Lemna minor*. In control experimental set the increase in DO was recorded to be 17.003±2.258%, while in experimental set with 100% *Lemna minor* recorded 62.376±6.18% increase. An increasing trend of DO along with time was noted in all the experimental sets except the experimental set where 100% *Eichhornia crassipes* was grown.

Percentage reduction in Biochemical oxygen demand is cited in figure-2. From the data obtained during the present investigation it was revealed that highest decrease in the Bio-chemical oxygen demand i.e. 73.55±4.9% was recorded in experimental set 4, after 56 days incubation. The decrease in Biochemical oxygen demand was least i.e. 16.683±1.25% in case of experimental set containing no macrophytes. A decreasing trend of BOD along with time was noted in all the experimental sets. A two way ANOVA showed a significant variation in different experimental sets ($p<0.005$) and different incubation period ($p<0.001$).

Similar trend was observed in case of COD reduction as represented in figure-3. The least COD reduction i.e. 16.913±1.5% was observed in experimental set 1, while highest COD reduction i.e. 73.622±4.71% was recorded in experimental set 4. A decreasing trend of COD along with time was noted in all the experimental sets. ANOVA showed a significant variation in different experimental sets ($p<0.001$) and different incubation period ($p<0.001$).

In case of NO_3-Nitrogen reduction as represented in figure-4, it was revealed that the NO_3-N reduction was least in experimental set 1 and maximum in experimental set 4. The NO_3-N reduction in experimental set 1 after 56 days incubation was 9.903±0.629% while in experimental set 4 it was 65.243±3.01%. In experimental sets 2 and 3 the reduction in NO_3-N after 56 days incubation was 55.167±5.204% and 44.967±7.78% respectively.

In case of PO_4-P reduction as represented in figure-5, it was noted that least reduction was observed in case of experimental set 1 and maximum reduction was observed in case of experimental set 4. The PO_4-P removal in case of set 1 was 4.023±1.233% while in case of experimental set 4, it was 86.25±5.25%. In experimental set 2 and 3 the reduction percentages were 82.51±4.91% and 76.423±4.804% respectively. ANOVA revealed significant variation in different experimental sets ($p<0.001$) and in different incubation period ($p<0.001$).

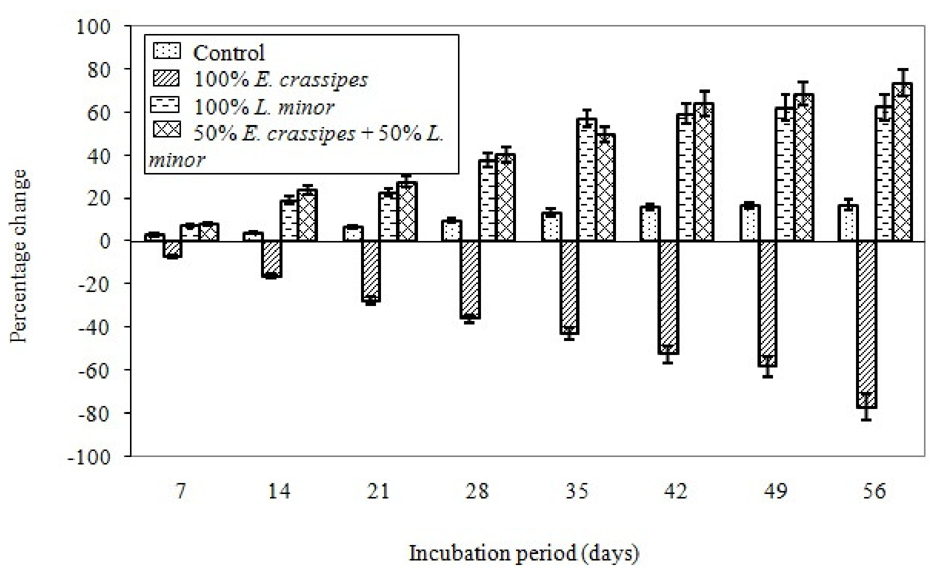

Figure-1
Percentage change in Dissolved Oxygen of polluted river water in different experimental sets
(Mean values of different incubation days; Vertical bars indicate + 1 SE)

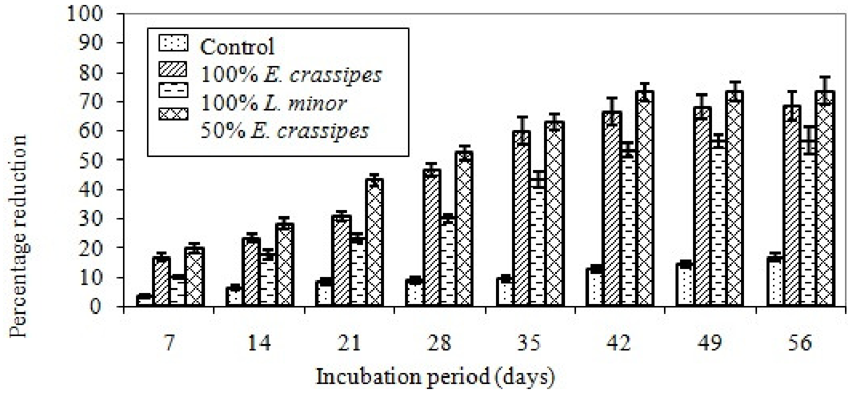

Figure-2
Percentage reduction in Bio-chemical Oxygen Demand of polluted river water in different experimental sets
(Mean values of different incubation days; Vertical bars indicate + 1 SE)

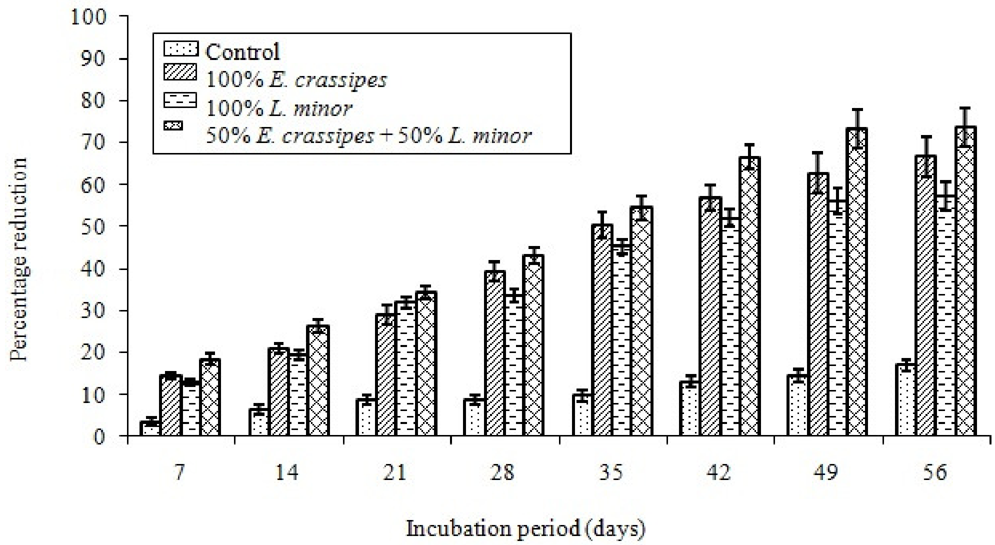

Figure -3
Percentage reduction in Chemical Oxygen Demand of polluted river water in different experimental sets
(Mean values of different incubation days; Vertical bars indicate + 1 SE)

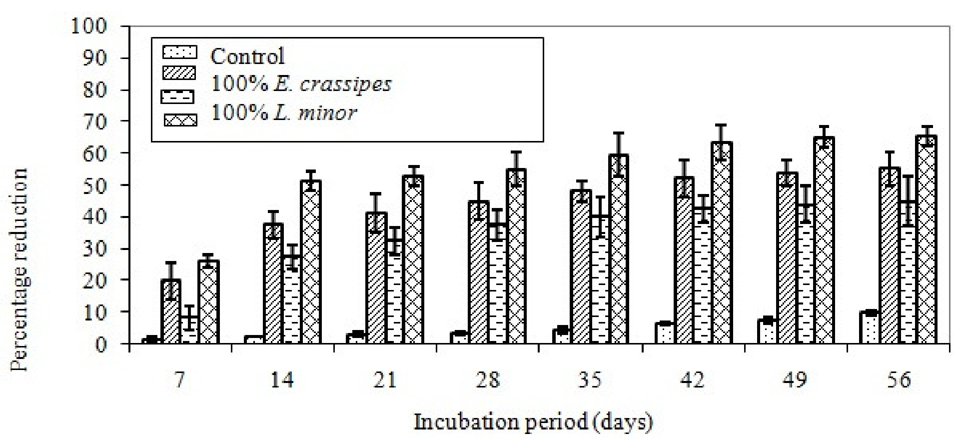

Figure-4
Percentage reduction in Nitrate content of polluted river water in different experimental sets
(Mean values of different incubation days; Vertical bars indicate + 1 SE)

Analysis of plant tissue (stem and leaf) of *Eichhornia crassipes* and *Lemna minor* indicated that large amount of crude protein and mineral nutrients were present in these plants. The crude protein content of plants before and after treatment is cited in table-1. The results revealed that crude proteins and other mineral nutrients increased in plant tissues after 56 days incubation. The crude protein in *Eichhornia crassipes* increased from 23.40 to 31.10 and in *Lemna minor* it increased from 25.60 to 32.90 after treatment. Based on the chemical composition data, if compared with chemical composition of animal feed as represented in table-2 and table-3 given by Sen and Ray[26]. The *Eichhornia crassipes* and *Lemna minor* appear to be potential, non-toxic food sources for animals. These aquatic plants can be easily harvested from the water bodies and may be powdered and mixed with other animal fodder crop plants to use it as animal feed.

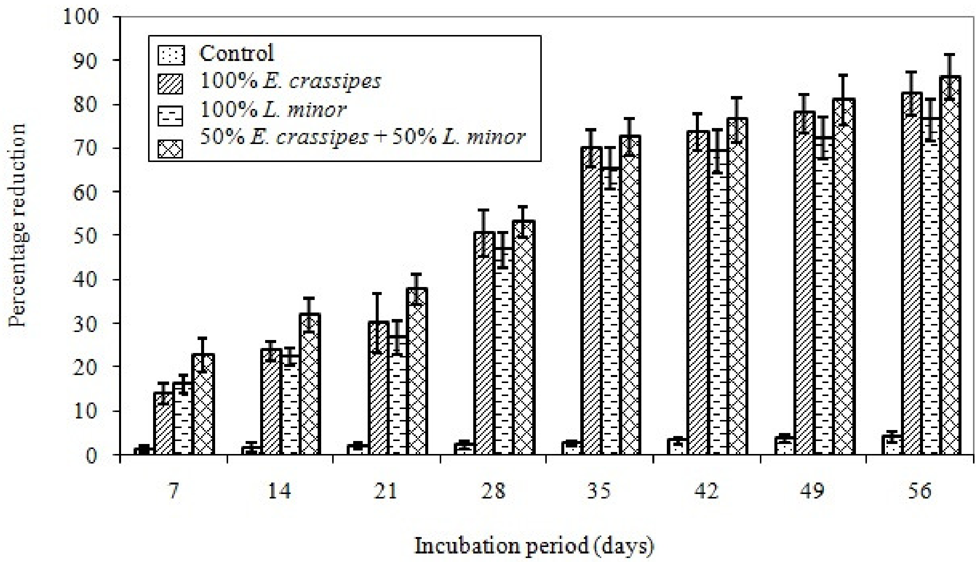

Figure-5
Percentage reduction in Phosphate content of polluted river water in different experimental sets
(Mean values of different incubation days; Vertical bars indicate + 1 SE)

Table-2
Chemical composition of water hyacinth (*E. crassipes*) and Duckweed (*L. minor*) plants grown in waste water[26]

Parameters	Water hyacinth composition (% dry weight)		Duckweed composition (% dry weight)	
	Initial	After 56 days grown in waste water	Initial	After 56 days grown in waste water
Crude protein	23.40	31.10	25.60	33.14
Ash	18.40	19.47	11.90	12.44
Phosphorus	0.56	0.830	0.97	12.46
Calcium	1.70	2.460	1.30	1.66
Potassium	3.80	4.170	2.89	3.74
Sodium	0.60	1.160	0.18	0.54
Magnesium	0.90	1.170	0.37	0.85

Table-3
Composition of selected crop plants used as animal feed in India[26]

Crop plants	Crude protein (%)	Crude fat (%)	Total ash (%)	Ca (%)	P (%)	Mg (%)	Na (%)	K (%)
Barseem	14.34	17.03	57.26	7.75	0.18	0.12	-	-
Paddy straw	3.42	36.73	41.14	17.87	0.07	-	-	-
Dry maize stock	11.10	1.90	80.66	1.94	0.41	-	-	-
Wheat bran	11.39	16.62	60.36	9.90	0.82	-	-	-
Mustard yellow	36.0	10.05	32.76	9.00	1.07	-	-	-
Linseed cake	30.57	9.98	43.24	10.10	0.96	0.54	0.35	0.76

Table-4
Composition of Animal feed

Content	For Milch Ration	For Dry Stock Ration
Crude protein (%)	26.0 (minimum)	18.0 (minimum)
Crude fat (%)	2.5 (minimum)	2.5 (minimum)
Crude fibre (%)	1.2 (maximum)	12.0 (maximum)
Moisture (%)	11.1 (maximum)	11.0 (maximum)

Poshan Agro Vet, Kanpur, India 1982

Conclusion

From the present experiment it is clear that the use of large leaved water hyacinth (*E. crassipes*) in combination with *Lemna minor* is economical, convenient and a useful technology for the wastewater treatment besides their use as animal feed.

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