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PHYTOREMEDIATION POTENTIAL OF DUCKWEED (*LEMNA MINOR* L: A TINY AQUATIC PLANT) IN THE REMOVAL OF POLLUTANTS FROM DOMESTIC WASTEWATER WITH SPECIAL REFERENCE TO NUTRIENTS

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ABSTRACT
Phytoremediation potential of Duck weed *Lemna minor* L. was studied invitro for the period of seven days to investigate the removal of pollutants in domestic wastewater with special reference to nutrients. The study was conducted in plastic tubs of six inches deep and of 175cm diameter. Twenty liter domestic wastewater was used in tubs for the culture of Duck weed. The domestic wastewater quality was assessed by analyzing Physico-chemical characters and obtained data was indicated as initial value. 100g of fresh weight of *Lemna minor* L was cultured for the period of seven days and again domestic wastewater was analyzed for the same Physico-chemical parameters and obtained values were indicated as final value. Net primary productivity (NPP) of Duck weed was also determined by Harvest method for the period of culture. The study revealed that pH, Dissolved oxygen and Percentage oxygen saturation value had increased, while the values for other studied Physico chemical parameters decreased significantly after seven days of culture of *Lemna minor* L. An increase in value of pH. Dissolved oxygen, Percentage oxygen saturation and decrease in value of Alkalinity, Carbon di oxide concentration, Chloride, and C.O.D., Hardness, Nitrogen and Phosphorus value indicated an improvement in water quality. An increase in fresh weight of *Lemna minor* L. and NPP value have suggested its great potential in Phytoremediation for removal of pollutants with special reference to nutrients like Nitrogen and Phosphorus from domestic wastewater.

INTRODUCTION

Domestic wastewater is producing in a huge quantity in almost all the cities of the country. Its disposal and treatment has become a challenge for the municipalities. Many of the municipalities in growing cities neither have proper disposal system nor have any treatment facility due to higher cost. In such a situation domestic wastewater is diverted in to low lying area in to aquatic bodies like ponds and lakes, where it is posing a serious threat to the water quality. Disposal of domestic wastewater in to fresh water bodies is constantly adding nutrients in to water, which is mainly responsible for increase in the concentration of nitrogen and phosphorus. The presence of nitrogen in wastewater is undesirable, because of ammonical form of nitrogen which is toxic to fish and many other aquatic organisms. It is also an oxygen-consuming compound, which can deplete the dissolved oxygen in water. The depletion of dissolved oxygen in water is a problem in aquatic ecosystems, since maintenance of high oxygen concentration is crucial for survival of most of the life forms in aquatic ecosystems.

Most of the domestic wastewater receiving ponds is facing a problem of eutrophication due to enrichment of nitrogen and phosphorus etc. Phosphorus removal and for wastewater purification using duckweed and water hyacinth has been recorded by Sutton and Ornes, 1975; Mandi, 1994 respectively. The water quality is altered and quite susceptible for the growth of Phytoplanktons and Macrophytes. An enormous growth of plants in these water bodies making water unhygienic to use and same time, it is causing serious threat to their existence. In such a condition there is an urgent need of a low cost technology for the treatment of domestic wastewater which every municipality can adopt. Treatment before disposal will also lower the impact of domestic wastewater on water bodies.

Viewing this fact Phytoremediation was assumed to be very useful, as it is an innovative, eco-friendly and efficient technology in which natural properties of plant is used in engineered system to remediate hazardous wastes from domestic wastewater and sewage. Phytoremediation technology based on the culture of aquatic plants in constructed wetlands and artificial ponds is increasingly applied to remediate nutrients from eutrophic water sources. Potential utility for removal of nutrients by some macrophytes like *Eichhornia crassipes, Pistia stratiotes* etc. has been tested by Cornell *et al.,* 1977; Reddy and Debusk, 1985; Aoi and Hayashi, 1996. Aquatic macrophytic based wastewater system containing floating macrophytes are most commonly utilized over the world. Constructed wetlands for wastewater treatment and management are of low cost, simple and easy to manage technology after construction (Hammer, 1992). Significance of constructed wetlands for wastewater treatment has been demonstrated by (Hammer, 1992 and House *et al.,* 1994).

The recent application of duckweed technology in wastewater treatment and management is quite interesting and revealing. Duckweed systems are one of the options that have been widely applied for combined handling of wastewater with the nutrients used for poultry and aqua-cultural projects (Gijzen and Kondker, 1997) and (Naphi *et al.,* 2003). Aquatic plants have shown their efficiency in absorbing nutrients from various sources of polluted water, (Janjit *et al.,* 2007). Floating plants are of well performers to treat wastewater (Zirschky and Reed, 1988).

In light of above knowledge, presented work was planned to study the Phytoremediation potential of Duck weed (*Lemna minor* L) in the removal of pollutants in domestic waste water with special reference to nutrients in laboratory condition.

MATERIALS AND METHODS

Phytoremediation potential of duckweed (*Lemna minor* L: a tiny aquatic plant) in the removal of pollutants in domestic waste water was determined in the Laboratory by performing culture experiment.

Culture Experiment

To access nutrient removal capacity of *Lemna minor* L from domestic wastewater, an off-site culture experiment was conducted throughout the year. Domestic wastewater was collected from the surface with the help of sampling bottles. 20L each domestic wastewater was taken in two plastic tubs of size 6 inches deep and a diameter of 175cms. 100g of fresh biomass of *Lemna minor* L was cultured in a tub for the period of seven days whereas one of them was used as control and again the fresh biomass was noted for the determination of Net primary productivity.

Analysis of domestic wastewater quality before and after the Phytoremediation

Domestic wastewater quality was determined by analyzing Physico-chemical parameters like Temperature, pH, Turbidity, Salinity, Electrical conductivity, Total dissolved solids, Alkalinity, Free carbon dioxide, Total carbon dioxide, Chloride, Dissolved oxygen, Percentage oxygen saturation, Chemical oxygen demand, Total hardness, Calcium hardness, Calcium, Magnesium, Nitrogen in Ammonical, Nitrite, and Nitrate form and Phosphate in monthly interval, before and after the Phytoremediation with the duck weed for seven days. The value before Phytoremediation was noted as initial value while the value recorded after the Phytoremediation was indicated by final value. All the analysis was done by following APHA-AWWA-WPCF-1980.

Net Primary Productivity (NPP) determination

Net Primary Productivity was determined by following Harvest method.

Bf - Bi/dt, Where

Bf: Final biomass, Bi: Initial biomass in g/m^{-2}/day

dt: Day interval (No. of days of Culture)

RESULTS AND DISCUSSION

Phytoremediation potential of Duck weed (*Lemna minor* L) in the removal of pollutants from domestic wastewater was studied by analyzing the domestic wastewater before and after the Phytoremediation by Duck weed. The value before and after the Phytoremediation and percentage changes was reported as initial and final value in Table 1 and Table 2 showing Net Primary Productivity of Duck weed in g/m^{-2}/day.

Domestic waste water quality before and after the Phytoremediation with Duck weed

Temperature is an important ecological factor, which plays an important role in chemical and biological reactions in plant body system. The maximum decrease in temperature was observed 16.03% in the month of December, while minimum 3.14% in the month of August. The reason of reduction was decrease in light penetration in the culture due to occupation of aquatic plant on the surface of culture. Temperature and light impact on water hyacinth was reported by Olga and Alenka (1989). pH value had exhibited little increase, maximum 10.47% in reference to the value before culture. An increase in pH level supports the growth of aquatic plant Vermaat and Hanif (1998). Turbidity was reduced maximum 41.75 % in the month of October. Salinity, Electrical conductivity (EC) and Total dissolved solids (TDS) were reduced below 5% throughout the study period except in the month of December for Salinity and November, December for TDS. The reason for the reduction of salinity, EC and TDS was absorption of dissolved solids by Duck weed in culture. Salinity influences growth of aquatic vegetation was studied by Haller *et al.* (1974) and Hammer (1992). Total alkalinity reduction was higher (18.28%) during the winter months due to partial utilization of bicarbonate ions. Percentage reduction of free carbon di oxide was more than 50% once in the study period during the month of December, while the Total carbon di oxide reduction value also recorded peak value of 25.72 % in the same month. The reason of this reduction was higher rate of carbon di oxide consumption in Photosynthesis. Chloride reduction in Phytoremediation was below 5% except in the month of December. The Chloride removal percentage is very less due to lower rate of absorption of chloride ion.

An increase was registered in Dissolved oxygen (DO) and Percentage oxygen saturation value throughout the year. Higher percentage increase was >100% for DO and oxygen saturation only in the month of February, while other months have very fluctuating value from 38.5 to 96.2% for DO and 24.3 to 80.2% for oxygen saturation. The reason for the increase in DO level during the winter is much growth of Duckweed and higher production of oxygen through photosynthesis and subsequently greater dissolution of oxygen in water due to decrease in dissolved solids. Moorhead and Reddy (1988) observed an increase in oxygen level after the culture of aquatic plants in domestic waste water due to exchange of oxygen from aerial tissue in to root zone.

The percentage reduction in Chemical oxygen demand (C.O.D.) value was higher 35.29% during the winter months than the other months. The decrease in value was registered due to an increasing D. O. level by Duck weed culture which provides better environment for oxidation.

Table 1: Phytoremediation of nutrients from domestic wastewater by a tiny aquatic plant (*"lemna minor* l")

S. No.	Parameters	Unit	Before phytoremediation Initial value range		After phytoremediation percentage change/reduction range	
			Minimum	Maximum	Minimum	Maximum
1	Temperature	ºC	24.80	36.60	3.14	16.03
2	pH	-	6.93	7.36	1.39	10.47
3	Turbidity	NTU	17.80	38.90	8.23	41.75
4	Salinity	$^0/_{00}$	0.37	0.90	0.90	6.15
5	Electrical Conductivity	micro mhos/cm	588.60	961.60	1.02	4.70
6	Total Disolved Oxygen	ppm	319.90	620.30	0.97	6.43
7	Total Alkalinity	$mgCaCO_3/L$	232.50	377.50	2.29	18.28
8	Free Co_2	mg/L	28.02	168.16	9.57	51.86
9	Total Co_2	mg/L	239.22	436.56	5.70	25.72
10	Chloride	mg/L	74.53	137.57	1.87	5.27
11	Dissolved Oxygen	mg/L	1.40	5.50	38.50	126.10
12	Oxygen Saturation	%	21.60	72.50	24.30	113.80
13	Chemical Oxygen Demand	mg/L	57.60	223.20	6.90	35.30
14	Total Hardness	$mgCaCO_3/L$	215.34	353.08	8.57	16.88
15	Calcium Hardness	$mgCaCO_3/L$	122.76	223.74	4.84	12.79
16	Calcium	mg/L	49.20	79.35	4.84	12.79
17	Magnesium	mg/L	12.45	37.43	12.18	39.36
18	Ammonical - N	mg/L	6.53	26.19	4.70	47.93
19	Nitrite - N	mg/L	0.31	0.48	15.68	34.78
20	Nitrate - N	mg/L	42.51	61.32	9.40	35.81
21	Total Ortho Phosphate	mg/L	0.53	0.89	18.87	38.78
22	Acid Hydrolyzable Phosphate	mg/L	0.22	0.52	16.35	48.79
23	Total Phosphate	mg/L	1.20	1.74	16.42	37.14
24	Organic Phosphate	mg/L	0.22	0.80	11.45	39.46

Table 2: Monthly variation in net primary producutivity gm. m $^{-2}$. day^{-1} of *Lemna minar* (oven dry biomass) after 07 days of culture in domestic wastewater during 2004. (Initial Biomass of *Lemna minar* Used for culture = 100 g)

Months	Period	Production $g\ m^{-2}$	N.P.P. $g\ m^{-2}\ day^{-1}$
Jan	15th -22nd	4.62	0.66
Feb	19th -26th	5.20	0.74
Mar	17th - 24th	2.89	0.41
Apr	12th -20th	2.31	0.33
May	12th -20th	2.89	0.41
Jun	16th - 23rd	3.46	0.49
Jul	06th - 13th	4.62	0.66
Aug	16th - 23rd	4.62	0.66
Sep	15th - 22nd	5.20	0.74
Oct	19th - 26th	5.78	0.82
Nov	16th - 23rd	7.51	1.07
Dec	14th - 21st	8.67	1.23
Mean $\bar{x}$	-	4.81	0.69
±SD	-	1.88	0.27

Percentage reduction in Total hardness was less < 20% while, Calcium hardness and Calcium value were reduced by < 15% after the Phytoremediation. The rate of reduction was higher during the winter months. Magnesium reduction value was >20% in few months, however did not exhibit any trend. The major cause of Hardness, Calcium and Magnesium reduction was utilization of Calcium and Magnesium by the Duck weed plant for body formation and development.

Nitrogen was analyzed in Ammonical, Nitrite and Nitrate nitrogen forms. The percentage reduction was maximum 47.93% for Ammonical nitrogen, 34.78% for Nitrite nitrogen and 35.81% for Nitrate nitrogen. The higher reduction rate was noted during the winter months. All the three forms were reduced after the Phytoremediation due to absorption by cultured aquatic plant Duck weed. Nitrate uptake by using *Lemna minor* was studied by Shen *et al.,* (2006).

Phosphorous content was determined in four forms viz. Total ortho, Acid Hydrolyzable, Total and Organic phosphate. The reduction in all the forms of Phosphate had exhibited similar range < 50% with peak values during the winter months. The cause of reduction in Phosphorus as phosphate was absorption by the Duck weed as a nutrient. Accumulation of various nutrients by aquatic plants depends on relative population in aquatic environment (Reddy *et al.,* 1990).

Estimation of Net Primary Productivity (NPP)

Net primary productivity was recorded <1g/m^{-2}/day except for the months November (1.07) and December (1.23). Higher values of NPP were recorded in the winter months while, lower in the summer months. The reason for higher NPP value during winter months was the suitability of growth conditions like Temperature and light. The storage of nutrients in floating aquatic plants is short term because of rapid turnover. If the experimented plants will not be harvested then after death and decomposition of the aquatic plant nutrients will be released back in to the water system, therefore, regular harvesting was done to avoid this process of release back of nutrients. Aquatic plants and their utility for biomass production were observed by Ripley *et al.,* (2006); Verma *et al.,* (2006); Chadwick and Obeid (1966).

Experimental aquatic plant Duck weed has a unique, efficient capacity for up-take of nutrients as well as increasing biomass under stipulated time. Although low Temperature, less concentration of nutrients, salty water etc. prevents the potentiality of the experimental aquatic plant to remove nutrients. Removal rate varied because of age, physiological capacity and pollution level.

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