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Waste Water Purification Potential of *Eichhornia crassipes* (Water Hyacinth)

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A B S T R A C T

Water hyacinth has been used in aquatic systems worldwide for waste water purification. It has tremendous capacity of absorbing nutrients and other substances from the water and hence brings the pollution load down. In the present study an attempt was made to find the potential of water hyacinth in the treatment of sewage water. Water hyacinth was cultured in the tank of approximately 5ft X 4ft X 2.5 ft dimension. The parameters studied were pH, EC, DO, COD, BOD, TDS, Turbidity and N, P, K. Two years of experimental investigation showed that water hyacinth reduced considerably all the physicochemical parameters and increased the dissolved oxygen (DO) to a significant level therefore it is concluded that *Eichhornia crassipes* is highly efficient in purification of sewage water in respect of physicochemical parameters.

Introduction

Pollution of water and soil is a major environmental problem and day by day, this problem is increasing with rapid growth of industrialization and urbanization in all parts of the world. Developing cost effective and environmentally friendly technologies for the remediation of soils and wastewater polluted with toxic substances is a topic of global interest. The value of metal- accumulating plants to wetland remediation has been recently realized (Black, 1995). This capability is useful in removing toxic heavy metals and trace elements from contaminated soils and waters in a process referred to as phytoremediation. This refers to the use of the green plants to clean up contaminated soil and polluted water bodies. The idea of using metal accumulating plants to remove heavy metals and other compound were first introduced in 1983, but the concept has actually implemented for the last 300 years (Henry, 2000). The generic term "Phytoremediation" consist of the Greek Prefix phyto (plants), attached to the Latin word remedial (to correct or remove an evil) (Prasad, 2004). Phytoremediation is an attractive alternative or complementary technology that can be used along with or in some cases in place of mechanical conventional cleanup treatments that often require high capital inputs, more labour and energy intensive (Cunningham *et al.*, 1996). It is less destructive to the environment, cost effective and aesthetically environmental pollutants removal approach is most suitable for developing countries (Shah, 2010; Pivertz, 2001). The plant used in the phytoremediation technique must have a considerable capacity of metal absorption, its accumulation and strength to decrease the treatment time (Mudgal *et al.*, 2010). It is the least harmful method which preserves the natural state of the environment and can reduce the maintenance cost indirectly.

Eichhornia crassipes is free floating aquatic plants in which roots play important role in removing nutrients (Reed Crites and Middle Brooks, 1995). It has tremendous capacity of absorbing nutrients and other substance from water (Boyed, 1970) and hence brings the pollution load down. It is found to be most effective in removal of BOD, COD, Nitrogen, phosphorus, organic carbon, suspended solids, phenols, pesticides, and heavy metals etc. from waste water (Gupta, 1982). In India, water hyacinth-based wastewater treatment plants (pilot/full-scale) are performing well with regards to reduction in BOD, COD, and total nitrogen reduction despite poor designing and vegetation management (Trivedy and Thomas, 2004). Moreover, suitable combination of water hyacinth with other aquatic plants such as duckweed and or blue green algae produce superior nutrient removal than water hyacinth alone (Sinha and Sinha, 2002; Tripathi and Upadhyay, 2003). The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing contaminant toxicity are found. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth, as well as other non-essential contaminants.

The purpose of the study is to utilize the aquatic macrophyte – water hyacinth (*Eichhornia crassipes*) as bio- filters and to observe potential of water hyacinth to remove pollutants present in sewage water.

Materials and Methods

Experimental site and experimental plant

The experiment was performed in the Department of Biological sciences of SHUATS, Allahabad (UP). *Eichhornia crassipes* was taken from Gangotrinagar, Indalpur road, Allahabad, U.P, washed thoroughly in running tap water to avoid any surface contamination, blotted with clean blotting paper for any surface moisture avoiding damage to root and leaf apices.

Collection of water sample

The sewage and tube well water samples were collected in polyethylene bottles rinsed with 20% HNO_3 followed by distilled water. The sewage water were collected from the sewage treatment plant Naini, Allahabad, U.P. and tube well water from research field of Department of Biological sciences of SHUATS Allahabad (UP).

Experimental design

Approximately 90-100 plants of young water hyacinth plants (12-15 gm fresh weight each) were cultured to tank approximately 5(ft) 4(ft) X 2.5(ft) in dimension and having capacity of 800 liters containing sewage water and tube well water covering approximately 75% surface area. Before transferring plants into tank, an initial analysis of main physical and chemical parameters of water sample was done. After 21 days, the analysis of treated sewage and treated tube well water were taken for different physical and chemical parameters. This experiment was repeated several times and finally data has been interpreted on average basis.

The experiment divided into 3 treatments

Treatment 1: 100% Tubewell water

Treatment 2: 100 % Sewage water

Treatment 3: 50% Tubewell water + 50% Sewagewater

Analysis of water sample

Several parameters of water were measured separately pH and EC by the procedure described by Allen (1974), Dissolve Oxygen (DO), Biological oxygen demand (BOD), Chemical Oxygen Demand (COD), Phosphorus (P), Nitrate nitrogen (NO_3-N) and Potasium (K) by Trivedy and Goel (1984), APHA(1985) and APHA(1999). Total dissolved solids (TDS) of the sample by digital TDS meter and Turbidity was measured by Nephlometric turbidity meter.

Results and Discussion

pH and EC

pH is the measurement of all the intensity of acidity or alkalinity and measure the concentration of hydrogen ion in water and EC indicate the total ionized constituents of water. In table 1–3 and figure 1 and 2 showed that pH and EC value after purification decreased significantly in all the three treatments in both the experimental years 2010-11 and 2011-12.

The pH and EC reduction by test plant (*Eichhornia crassipes*) was maximum in T_2 treatment. pH from 7.85 to 7.2 in year 2010-11 and from 7.82 to 7.1 in 2011-12. While EC decreases from 1.12 dsm^{-1} to 0.63 dsm^{-1} in year 2010-11 and (56.14%) from 1.14 dsm^{-1} to 0.50 dsm^{-1} in 2011-12. This reduction in pH is due to absorption of pollutants by plant and EC due to uptake of ions by plants.

Similar findings had also been reported by Dipu *et al.*, (2010), Yadav *et al.*, (2011), Dhote (2007), Shah (2010), Mahmood *et al.*, (2005).

Dissolved oxygen

In table 4 and figure 3 DO value increased significantly in all the three treatments in both the experimental years 2010-11 and 2011-12. The DO increase by test plant (*Eichhornia crassipes*) was maximum in T_2 treatment (537.73%) in year 2010-11 and (501.0%) in 2011-12. The DO increase in T_1 treatment was minimum (41.53%) where it increases from 6.50 mgL^{-1} to 9.20 mgL^{-1} in year 2010-11 and from 6.2 mgL^{-1} to 9.6 mgL^{-1} in 2011-12.

Photosynthesis helps in maintaining the oxygen supply for plants while respiration helps in maintaining dissolved oxygen content in the water. The photosynthetic activities in plants increase the DO in water, thus creating aerobic conditions in the system (Yadav *et al.*, 2011; and Bastviken S. 2006).

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD is the amount of oxygen that will be consumed by microorganism during the biological reaction of oxygen with organic material and COD tells how much oxygen is needed to fully oxidize any quantity of some compounds containing either carbon, hydrogen or both. The BOD reduction by test plant (*Eichhornia crassipes*) was maximum in T_3 treatment (77.24%) where it decreases from 69.0 mgL^{-1} to 15.7 mgL^{-1} in year 2010-11 and (67.75%) from 80.0 mgL^{-1} to 25.0 mgL^{-1} in 2011-12. The COD reduction by test plant (*Eichhornia crassipes*) was maximum in T_1 treatment (87.60%) in year 2010-11 and (84.15%) in 2011-12. The reduction in BOD and COD can be attributed to many reasons. Aquatic plants have the unique feature of transporting oxygen from the aerial plant portions to the submerged parts significantly increase the sub canopy oxygen content of water (Adeola *et al.*, 2009).

Table.1 Average percent reduction in physio-chemical characteristics of Tubewell water (T_1) treated by *Eichhornia crassipes* (2010-11) and (2011-12)

	2010-11			**2011-12**		
Parameters analysed	Tubewell water	Treated Tubewell water	Average %age reduction	Tubewell water	Treated Tubewell water	Average %age reduction
pH	7.6	7.4	2.65%	7.7	7.4	3.8%
EC dsm $^{-1}$	0.49	0.28	42.85%	0.46	0.29	36.95%
BOD mg L^{-1}	2.66	0.93	65.00%	2.0	0.90	55.00%
COD mg L^{-1}	9.68	1.2	87.60%	10.1	1.6	84.15%
TDS mg L^{-1}	371.33	227.66	38.00%	390.33	235.10	39.70%
Turbidity NTU	2.61	1.52	41.76%	2.80	1.49	46.78%
NO_3-N mg L^{-1}	0.37	0.15	59.45%	0.39	0.18	53.84%
P mg L^{-1}	0.04	0.01	75%	0.06	0.021	83.3%
K mg L^{-1}	00.1493	0.1084	27.19%	0.1693	0.1101	34.96%

Table.2 Average percent reduction in physio-chemical characteristics of Sewage water (T_2) treated by *Eichhornia crassipes* (2010-11) and (2011-12)

	2010-11			**2011-12**		
Parameters analysed	Sewage water	Treated Sewage water	Average %age reduction	Sewage water	Treated Sewage water	Average %age reduction
pH	7.85	7.2	8.28%	7.82	7.1	9.20%
EC dsm $^{-1}$	1.12	0.63	43.75%	1.14	0.50	56.14%
BOD mg L^{-1}	136.6	52.1	61.85%	156.6	56.1	64.17%
COD mg L^{-1}	196.0	36.3	81.47%	200.1	40.8	79.61%
TDS mg L^{-1}	630	383	39.20%	660	390	40.90%
Turbidity NTU	43.66	2.93	93.28%	50.10	3.00	94.0%
NO_3-N mg L^{-1}	1.32	0.80	37.12%	1.41	0.83	41.1%
P mg L^{-1}	0.0	0.36	55.5%	0.80	0.30	62.5%
K mg L^{-1}	0.3743	0.2823	24.5%	0.391	0.251	35.8%

Table.3 Average percent reduction in physio-chemical characterstics of {50% sewage + 50% Tubewell} (T_3) water treated by *Eichhorniacrassipes* (2010-11)

	2010-11			**2011-12**		
Parameters analysed	50% sewage + 50 % Tubewell	Treated (50% sewage + 50 % Tubewell)	Average %age reduction	50% sewage + 50 % Tubewell	Treated (50% sewage + 50 % Tubewell)	Average %age reduction
pH	7.69	7.2	6.3%	7.60	7.2	5.26%
EC dsm $^{-1}$	0.81	0.57	29.62%	0.91	0.61	32.9%
BOD mg L^{-1}	69.0	15.7	77.24%	80.0	25.8	67.7%
COD mg L^{-1}	96.33	23.5	75.60%	92.0	20.1	78.0%
TDS mg L^{-1}	491.6	311.3	36.67%	465.2	290.0	37.6%
Turbidity NTU	21.04	2.05	90.25%	19.3	4.1	78.7%
NO_3-N mg L^{-1}	0.76	0.50	34.21%	0.78	0.60	23.0%
P mg L^{-1}	0.37	0.16	56.75%	0.41	0.21	48.7%
K mg L^{-1}	0.2773	0.2013	27.40%	0.307	0.217	29.31%

Table.4 Average percent increment in dissolved oxygen (DO) of Tubewell water (T_1), sewage water (T_2) and [50% sewage + 50% Tubewell] water (T_3) treated by *Eichhornia crassipes* (2011-12)

Dissolved Oxygen	2010-11			2011-12		
Treatment(s)	Before Treatment	After Treatment	Average %age increment	Before Treatment	After Treatment	Average %age increment
Tubewell water (T_1)	6.5	9.2	41.53%	6.2	9.0	54.83%
Sewage water (T_2)	1.06	6.76	537.73%	1.00	6.01	501.00%
50% sewage + 50%Tubewellwater(T_3)	3.7	8.4	127.02%	4.1	7.56	84.39%

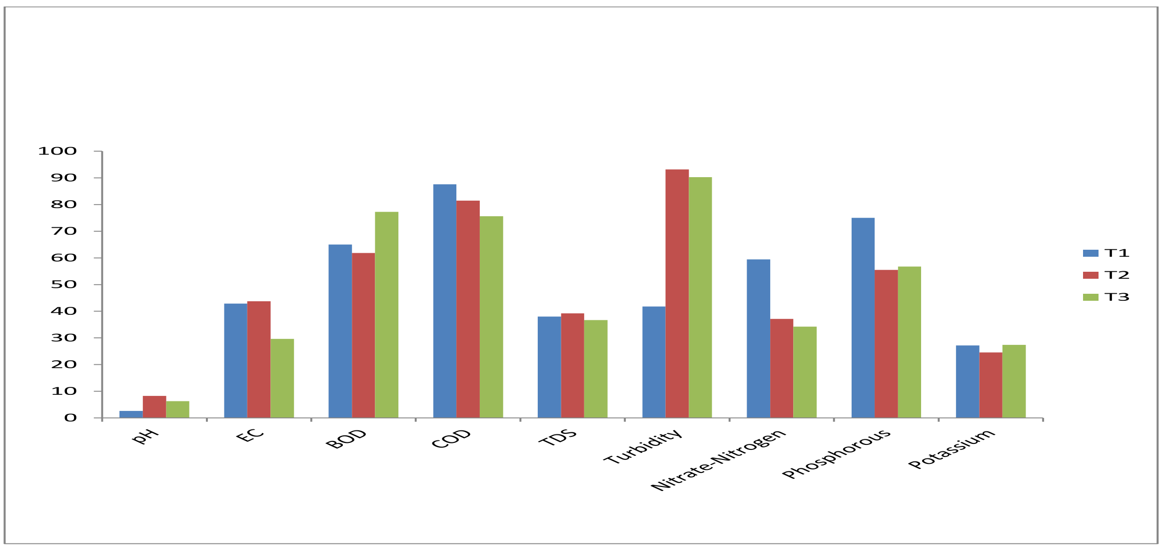

Fig 1 Average percent reduction in physio-chemical characteristics of T1,T2 and T3 treated by *Eichhornia crassipes* (2010-11).

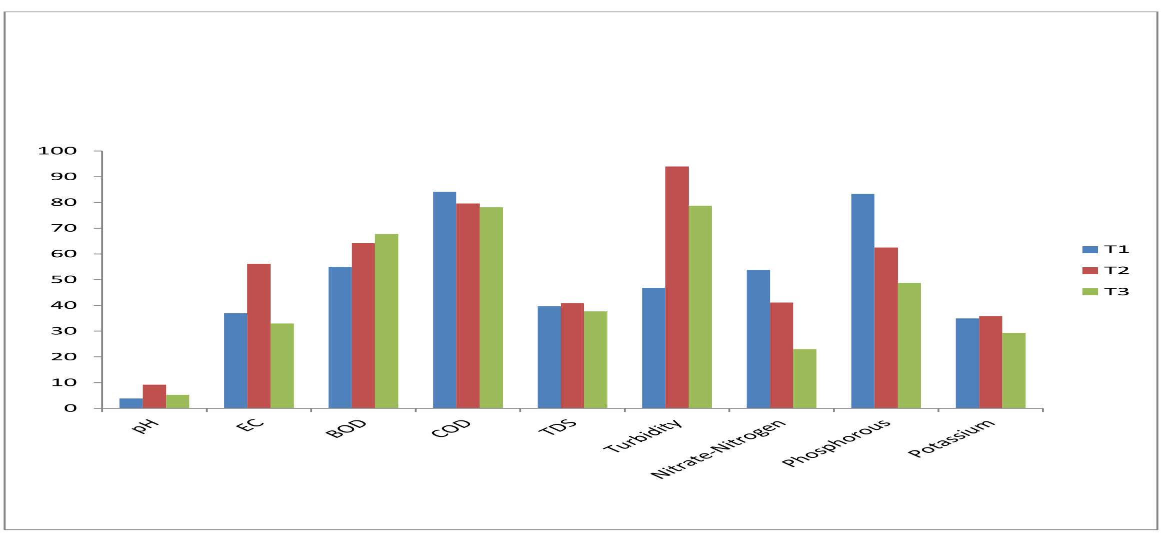

Fig 2 Average percent reduction in physio-chemical characteristics of T1,T2 and T3 treated by *Eichhornia crassipes* (2011-12).

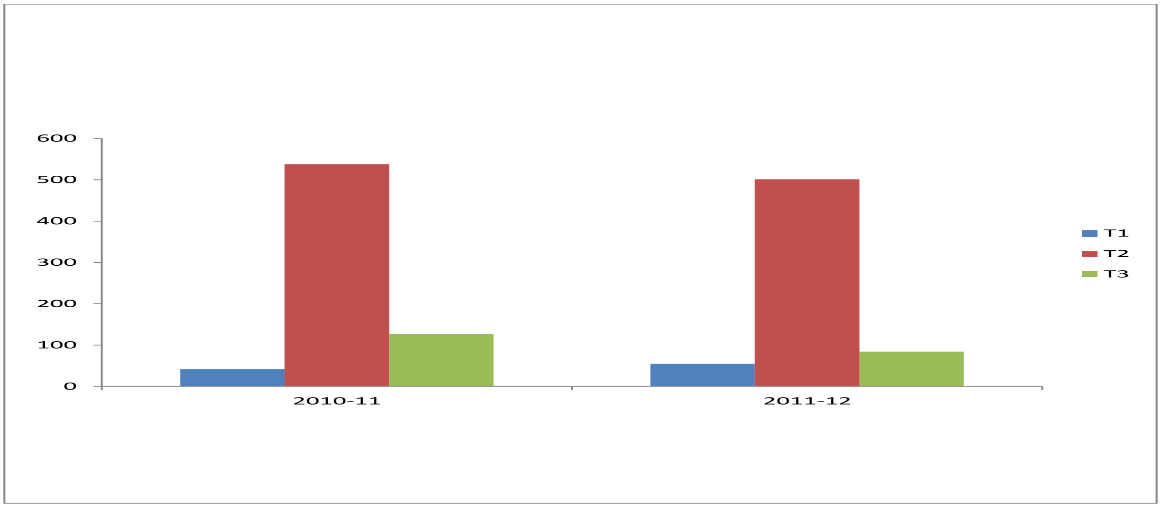

Fig 3 Average percent increment in dissolved oxygen by *Eichhornia crassipes* in all three treatments (T1, T2, T3) for the year 2010-11 and 2011-12.

Oxygen transfer by aquatic plants in to the root zone plays a significant role in supporting the growth of aerobic bacteria in the root zone and subsequent degradation of waste water carbon (Reddy and Debusk, 1987). Moreover, the higher suspended solids in the effluent samples help in enhanced microbial activity as additional substrate on the roots of aquatic plants. The reduction in pH favoured microbial action to degrade BOD and COD in the waste water. Similar finding had also been reported by Zimmels *et al.*, (2006), Zhang *et al.*, (2007), Haris (2007), Tegegne *et al.*, (2008), Dipu *et al.*, (2010), Shah (2010) and Dhote (2007).

Total dissolved solids (TDS) and turbidity

TDS are often used to express the degree of contamination or amount of impurities in water and wastewater and Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The result showed that TDS and Turbidity value decreased significantly in all the three treatments. The total dissolved solid reduction by test plant (*Eichhornia crassipes*) is almost similar in all three treatments for both the years. Similar findings had also been reported by (Dipu *et al.*, 2010; Shah 2010; Groudev *et al.*, 2001 and Wirojanagud *et al.*, 2002.) The turbidity reduction by test plant (*Eichhornia crassipes*) was maximum in T_2 treatment and minimum in T_1 treatment where it decreases from 2.61 NTU to 1.52 NTU in year 2010-11 and from 2.80NTU to 1.49 NTU in 2011-12. This reduction in turbidity is due to the root hairs as they have electrical charges of colloidal particles such as suspended solids and cause them to adhere on the roots where they are slowly digested and assimilated by the plant and microorganism. Similar findings had also been reported by (Johnston, 1993; Gudekar and Trivedi, 1989; Dipu *et al.*, 2010; Neralla *et al.*, 2007).

Nitrogen, phosphorus and potassium

NPK are very important polluting constituents of domestic wastewater because of their role in algal growth and eutrophication of water bodies. In the table 1–3 and figure 1 and 2 showed that NPK value after purification decreased significantly in all the three treatments in both the experimental years

2010-11 and 2011-12. The NPK reduction by test plant (*Eichhornia crassipes*) was maximum in T_1 treatment. The major removal mechanism for nitrogen is nitrification-denitrification. Ammonia is oxidized to nitrate by nitrifying bacteria in aerobic zones, and nitrates are converted to dinitrogen gas (N_2) by denitrifying bacteria in anoxic zones. The oxygen required for nitrification is delivered either directly from the atmosphere through the water or sediment surface, or by leakage from plant roots. Nitrogen is also taken up by plants and incorporated into the biomass. Similar findings had also been reported by Al-Omari (2003), Sommer (2000), Dipu *et al.,* (2010), Baskar (2001) and Shah (2010).

The phosphorus reduction in T_2 treatment was 55.5% where it decreases from 0.81mgL^{-1} to 0.36 mgL^{-1} in year 2010-11 and from 0.80 mgL^{-1} to 0.30 mgL^{-1} in 2011-12. Phosphorus removal occurs mainly as a consequence of adsorption, complexation and precipitation reactions with Aluminium (Al), Iron (Fe), Calcium (Ca) and clay minerals in the sediment. Alternate wet and dry periods enhance the fixation of phosphorus in the sediments. Similar findings had also been reported by Dhote (2007), Vymazal (2004), Wetzel (2001) and Yadav *et al.,* (2011).

The potassium reduction by test plant (*Eichhornicrassipes*) is almost similar in $T_{1,}$ and T_3 in year 2010-11, while similar reduction is found in $T_{1,}$ and T_2in the year 2011-12.Potassium is transformed in the wetland by a complicated biogeoghemical cycle. The major processes responsible for potassium removal were adsorption, precipitation and plant uptake rates (Vymazal 2004).Similar findings had also been reported by Dhote (2007).

In view of two years of experimental investigation it is concluded that *Eichhornia crassipes* is highly efficient in purification of sewage water in respect of physicochemical parameters. *Eichhornia crassipes* showed significant reduction in pH, EC, COD, BOD, TDS, Turbidity and N, P, K. This ability of macrophyte to absorb nutrients in largequantites can be utilized for at least primary and secondary treatment, if artificial aquatic systems are developed in a proper way. Moreover, as the *Eichhornia* plant is found in plenty and the conventional treatment process is very costly with high operational and maintenances cost thus it is justifiable to use *Eichhornia* plant as a low cost, eco-friendly and effective source of treatment of sewage water.

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