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Study of Domestic Sewage Treatment Using Aquatic Macrophyte Duckweed (*Lemna minor*)

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In this study, laboratory scale experiments on duckweed covered domestic sewage were carried out to evaluate the removal efficiency of duckweed species *Lemna minor* as a domestic wastewater stripper. The outdoor experiments were conducted in 4 mini ponds at Jodhpur. The physico-chemical properties of domestic wastewater were evaluated before and after inoculation of culture for wastewater quality improvement. Various parameters namely pH, DO, TSS, TDS, turbidity, BOD, COD, total nitrogen and total phosphorus were analyzed for varying detention periods. The result indicated treated effluent suitability for irrigation reuse purpose.

Key Words: Wastewater, Duckweed, Phytoremediation, *Lemna minor*.

INTRODUCTION

The effective wastewater remediation is a challenge to many developing nations. The conventional treatment technologies to reduce organic compounds and nutrient levels in domestic wastewater are too costly and energy intensive process posing difficulties in implementation particularly in developing nations. Moreover this approach does not encourage reuse of valuable energy and nutrient resources contained in the wastewater.

Macrophyte based wastewater treatment systems (Phytoremediation) have several potential advantages compared to conventional treatment systems[1]. Aquatic macrophytes have been suggested as a low cost option for the purification of wastewater and production of plant biomass[2], water hyacinth (*Eichhornis crassipes*), pennywort (*Hydrocotyle umbellata*), water lettuce (*Pistia stratiotes*) and duckweed (*Lemnaceae*) have been reported for the efficient removal of nutrients[3]. Although water Hyacinth is widely used for nutrient uptake, but the plant biomass application is yet to be identified.

The use of duckweed for wastewater remediation has been advocated because of rapid growth rates[4,5], low fibre and high protein content[4,6]. Furthermore duckweed can be easily harvested and appears to suppress algal growth[6].

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Duckweed is floating aquatic macrophyte belonging to botanical family lemnaceae which can be found worldwide on the surface of nutrient rich fresh and brakish waters.

The lemnaceae family consist of four genera (*Lemna, Spirodella, Wolffia* and *Wolfiella*). As compared to most other plants, duckweed has a low fibre content (about 5 %) since it does not require tissue to support leaves and stems[7,8]. A small cell in the pond divides and produces a new frond capable of producing 10 to 20 new fronds during its life cycle. The principle energy source for these systems is the solar energy[1].

The use of duckweed in wastewater treatment is not well documented nor is design criteria available. The scarce studies reported so far suggest that this technology holds great promise as a low cost wastewater treatment. It is against this background that the present study was carried out at Jodhpur to investigate the potential of duckweed for domestic sewage remediation. This paper presents the results obtained from laboratory scale experiments conducted in outdoor batch reactors on duckweed covered domestic sewage.

EXPERIMENTAL

The experiments were conducted on 4 mini shallow batch reactors R1, R2, R3 and R4 constructed of brick masonry with all sides' water proofed with cement plaster in the open space available in the Environmental Engineering Laboratory of the Department of Civil Engineering, M.B.M. Engineering College, Jodhpur. The city of Jodhpur known as Sun City of India is situated on the marginal east of the world famous Thar Desert. Each of the four reactors was of size 90 cm × 80 cm in plane. The depth of reactor R1, R2, R3 and R4 were 15, 25, 35 and 45 cm, respectively. A free board of 5 cm was provided in each reactor. Raw wastewater was received from the Mahamandir-Punjala zone of Jodhpur and added to the four reactors upto the depth of 10, 20, 30 and 40 cm, respectively and tested for pH, temperature, dissolved oxygen (DO), total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP).

Duckweed (*Lemna minor*) plants were collected from the historical pond at Shani temple near Mehrangarh Fort at Jodhpur. The stocks were cleaned by tap water and transferred to the ponds for aquatic treatment. The domestic wastewater was kept under outdoor local environment condition for 28 days hydraulic retention time (HRT) starting from 2nd June 2008. Subsurface (Under Duckweed mat) wastewater sample for physico-chemical analysis were collected for examination with frequency of every 7 days till 28 days. The duckweed harvested after every 5 days was 20 % of the surface area in each reactor. The physico-chemical analyses were carried out according to standard methods of examination of water and wastewater[9].

RESULTS AND DISCUSSION

The results of the analysis of domestic wastewater characteristics at an interval of every 7 days of culture of *Lemna minor* till 28 days in different reactors R1, R2, R3 and R4 are given in Table-1. It showed that values of pH were in alkaline scale and ranged between 7.61 as minimum at zero day and 7.84 in reactor R4 as maximum after 14 days of treatment. A pH of around 7.5 was found to be most ideal for optimum pond performance[10]. Sewage temperature is one of the crucial design parameters for duckweed Pond system[11]. In the present study, temperature ranged between 30.5 to 34.5 ºC, which is within the upper tolerance limit of around 34 ºC[12] for duckweed growth.

As per the results in Table-1, TSS decreased by increasing the hydraulic retention time, reaching a minimum concentration of 25 mg/L after 28 days in the reactor R1 and R2. Total dissolved solids recorded the minimum value of 90 mg/L in reactor R3 after 28 days HRT. The duckweed cover restricts sunlight penetration and this, in turn, limit algal development and further improve performance in respect to TSS removal. The DO concentration showed gradual increase from 1 mg/L initially to 6.4 mg/L after 28 days of hydraulic retention time in reactor R1.

The BOD, COD, total nitrogen (TN), total phosphorus (TP) showed gradual removal over a period of time. Duckweed was found to substantially remove total nitrogen and total phosphorus from wastewater which is crucial in controlling eutrophication problem particularly when the treated effluent is discharged in the receiving water body. BOD removal was more than 85 % in all reactors whereas COD removal was more than 60 % in all reactors. Around 70 % removal of TN was recorded in all reactors whereas the TP removal was more than 80 %. It was observed that higher pollutant removal efficiency was found in the reactor with lower water column depth. This is attributed to higher surface area of duckweed culture to per unit volume of wastewater. The duckweed harvested after every 5 days was 20 % of the surface area in each reactor. It was observed that the duckweed immediately spread out and covered the exposed surface after harvesting. The standing crop density of duckweed is much lower than other plants indicating its versatility in operation and high specific productivity.

According to I.S. 2296 and I.S. 2409-1974, the effluent standard acceptable for agriculture and gardening use should limit BOD to 12-20 mg/L, total solids to 30-200 mg/L and suspended solids[13] to 30 mg/L. In the present study, domestic sewage treated with duckweed system shows more or less same concentration as B.I.S., therefore the effluent may be used for agricultural and gardening purpose economically after this low cost treatment.

Conclusion

This study reveals that duckweed based wastewater treatment system is effective in water pollution control. Phytoremediation of wastewater using duckweed as stripper is an attractive option particularly in areas where sunshine availability is in plenty.

TABLE-1
EFFECT OF AQUATIC TREATMENT WITH *Lemna Minor* ON PHYSICOCHEMICAL CHARACTERISTICS OF DOMESTIC WASTEWATER IN DIFFERENT REACTORS R1-R4 DURING JUNE 2008

Time (day)	Temp. (ºC)	pH	mg/L									Reduced (%)							
			DO	TSS	TDS	TS	BOD	COD	TN	TP	Turbidity	TSS	TDS	TS	BOD	COD	TN	TP	Turbidity
Reactor 1																			
0	30.5	7.61	1.0	260	375	635	144.6	239.00	30.4	4.60	113.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	34.5	7.68	3.0	105	225	330	61.80	122.40	20.36	2.65	45.65	59.61	40.00	48.03	57.26	48.78	33.02	42.39	59.82
14	32.00	7.71	3.8	65	165	230	28.30	108.00	15.05	1.25	27.46	75.00	60.00	63.78	80.42	54.81	50.49	72.82	75.83
21	33.00	7.64	4.8	40	130	170	18.30	94.60	10.65	0.90	17.49	84.61	65.33	73.23	87.34	60.67	60.97	80.43	84.60
28	33.5	7.62	6.4	25	125	150	16.60	87.00	8.91	0.75	11.26	90.38	66.66	76.38	88.52	63.60	70.69	83.69	90.10
Reactor 2																			
0	30.5	7.61	1.0	260	375	635	144.6	239.00	30.40	4.60	113.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	34.5	7.68	3.0	115	195	310	71.30	128.60	21.90	2.52	50.54	55.77	48.00	51.18	50.69	46.19	27.96	45.22	55.62
14	32.00	7.72	3.6	55	170	225	35.60	118.30	16.75	1.85	23.91	78.84	54.66	64.57	75.38	50.50	44.90	59.78	78.96
21	33.00	7.68	4.8	40	115	155	20.00	101.00	11.55	1.10	17.39	84.61	69.33	75.59	86.17	57.74	62.00	76.08	84.67
28	33.5	7.70	6.2	25	110	135	20.00	90.40	9.25	0.85	10.76	90.38	70.66	78.74	86.17	62.17	69.57	81.52	90.53
Reactor 3																			
0	30.5	7.61	1.0	260	375	635	144.6	239.00	30.4	4.60	113.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	34.5	7.64	3.2	125	210	335	74.00	128.40	22.75	2.55	54.74	51.92	44.00	47.24	48.82	46.44	25.16	44.56	51.82
14	32.00	7.82	3.4	65	135	200	41.30	112.00	16.72	1.78	28.86	75.00	64.00	68.50	71.44	53.14	45.00	61.30	74.60
21	33.00	7.75	4.4	45	90	135	23.60	96.20	11.55	1.10	19.76	82.69	76.00	78.74	83.68	59.75	62.00	76.08	82.62
28	33.5	7.80	6.0	30	90	120	18.30	89.60	9.40	0.80	12.76	88.46	76.00	81.10	87.34	62.51	69.08	82.61	88.77
Reactor 4																			
0	30.5	7.61	1.0	260	375	635	144.6	239.00	30.40	4.60	113.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	34.5	7.64	3.0	130	225	335	74.30	132.40	23.71	2.40	55.32	50.00	40.00	47.24	48.61	44.77	22.00	47.83	51.31
14	32.00	7.84	3.4	85	160	245	44.60	119.20	16.10	1.80	36.17	67.30	57.33	61.42	69.15	50.12	47.04	60.86	68.17
21	33.00	7.81	4.4	45	100	145	25.00	101.00	11.80	1.10	19.14	82.69	73.33	77.16	81.33	57.74	61.20	76.08	83.15
28	33.5	7.72	6.2	30	95	125	18.30	92.00	9.40	0.88	12.87	88.46	74.67	80.31	87.34	61.50	69.08	80.86	88.67

The duckweed plants provide suitable environment for microorganism to transform pollutants and reduce their concentrations. Duckweed is found to be efficient contaminant removal under optimum operational conditions. System is found to be simple in terms of operation and maintenance and therefore suitable for rural communities where availability of land is not a problem.

The harvesting is found to be simple compared to water hyacinth. The overall efficiency of duckweed based sewage treatment is promising especially at lower water column depth. The water supply system can be relieved from extra demand as the effluent meets the reuse criteria for agriculture and gardening. Avenues of income generation from selling dry duckweed as useful by-product needs to be explored from economic, financial and socio-cultural aspects. System optimization studies including that of harvesting regimes are necessary to have optimum results.

REFERENCES

1. A. Singhal and R.P. Mathur, *Indian J. Environ. Protec.*, **25**, 385 (2005).
2. G. Oron, *Agric. Water Manag.*, **26**, 27 (1994).
3. H.J. Gijzen, In Proceedings of International Symposium on Low Cost Wastewater Treatment and Reuse, Cairo, Egypt, pp. 13-22 (2001).
4. E. Landolt, The Family of Lemnaceae: A monographic Study, Ver.Geobotanischen 71, Institute ETH, Stifung Rubel, Zurich, Vol. 1, p. 566 (1986).
5. J.E. Vermaat and M.K. Hanif, *Water Res.*, **32**, 2569 (1998).
6. O. Hammouda, A. Gaber and M.S. Abdel-Hameed, *Enz. Microb. Tech.*, **17**, 317 (1995).
7. Innocent Nhapi, *Water Sci. Tech.*, **30**, 115 (2004).
8. W.A. El-Khair, G. Ismail, F.A. El-Nour, T. Tawfik and D. Hammad, *Int. J. Agric. Bio.*, **9**, 681 (2007).
9. APHA, Standard Methods for Examination of Water and Wastewater APHA, AWWA, WEF, Washington DC, edn. 21 (2005).
10 J.M. Dalu and J. Ndamba, In Proceedings of 3rd WaterNet/Warsa Symposium on Water Demand Management for Sustainable Development, Dar-es-salam, pp. 1-13 (2002).
11. S. Korner, J.E. Vermaat and S. Veenstra, *J. Environ. Qual.*, **32**, 1583 (2003).
12. G.A. Culley, E. Rejmankova, J. Kvet and J.B. Frey, *J. World Maric. Soc.*, **12**, 27 (1981).
13. G. Oron, in eds.: O. Mehmet and H.A. Bicak, Effluent Reuse for Agricultural Production; In: Mordern and Traditional irrigation Technologies in the Eastern Mediterranean, International Development Research Centre, Canda, Ch. 9 (2002).

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