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Wastewater Reclamation Using Floating Aquatic Macrophyte

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Abstract— During recent times the water scarcity problem has escalated manifold owing to rapid industrialization, urbanization, population explosion etc. The freshwater resources are shrinking rapidly further due to discharge of untreated wastewater into fresh water bodies making them unfit for public use and agriculture in many developing countries. India with agro based economy necessitates Effective and affordable wastewater treatment to reclaim it for subsequent use for agriculture purpose. This paper focuses on wastewater treatment using floating aquatic weed *Lemna minor* as a natural biological tool for wastewater reclamation.

Keywords- Wastewater, Duckweed, *Lemna minor*, Phytoremediation

I. INTRODUCTION

Water is precious natural resource available to mankind. It is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies, leading to tensions, conflicts among users, and excessive pressure on the environment. The increasing stress on freshwater resources brought about by ever-rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern. The per capita water availability for India was over 5000 m^3 per annum in 1950, which declined to 2000m^3 in 2001 and is projected to be only 1500 m^3 in 2025 [6]. Such quantitative data does not take into consideration the continued pollution of rivers and groundwaters – the major sources of available water. Due to lack of proper water treatment facilities a sizable area of cultivable land is deprived of water required for healthy agricultural returns. Sustainability and quality of water would be the biggest challenge before the nation in the coming future as the raw water quality will continue to deteriorate since all water supplies end up as wastewater leading to water scarcity.

Water scarcity means that water demand exceeds the water resources exploitable under sustainable conditions. Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system. Typically, water use is categorized by its three major uses: agriculture, industry, and domestic consumption often measured as municipal use. In global terms agriculture is seen as the sector that uses the most water. The volumes of industrial water withdrawal vary depending on the type of industry, the different kinds of production, and the technology used in the industrial process. In addition to water consumption, industrial water use is one of the main causes of water pollution in the world. With increasing population and its legitimate demand for improved livelihood, entailing expansion of industrial and agriculture sectors, there is an enormous challenge in the allocation, use and protection of limited water resources. Water demand management and concepts like “more crop, nutrition and services per drop” are essential elements to all water resource providers.

The effective wastewater treatment for its reclamation 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. Macrophyte based wastewater treatment systems (Phytoremediation) have several potential advantages compared to conventional treatment systems [2]. Aquatic macrophytes have been suggested as a low cost option for the purification of wastewater and production of plant biomass [11; 14], water hyacinth (*Eichhornis crassipes*), Pennywort (*Hydrocotyle Umbellata*), water lettuce (*Pistia Stratiotes*) and Duckweed (*Lemnaceae*) have been reported for the efficient removal of nutrients [3; 7; 10]. Although water Hyacinth is widely used for nutrient uptake, but the plant biomass application is yet to be identified.

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 [8; 15]. 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 [13]. This paper presents the results obtained from laboratory scale experiments conducted outdoor in batch reactors on floating aquatic macrophyte duckweed *lemna minor* covered domestic sewage assessing its suitability for agriculture reuse.

II. MATERIALS AND METHODS

The Experiments were conducted on one mini shallow batch reactor, R1 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 depth of reactor R1 was 35 cm. A free board of 5 cm was provided in the reactor. Raw wastewater was received from the Mahamandir-Punjala zone of Jodhpur and added to the reactor upto the depth of 30 cm and tested for pH, temperature, D.O., TSS, TDS, BOD, COD, TN and 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). Subsurface (Under Duckweed mat) wastewater sample for Physico-chemical analysis were collected for examination with frequency of every 8 days till 28 days. The Physico-chemical analyses were carried out according to Standard methods of examination of water and wastewater [1].

Table 1. Effect of Aquatic Treatment with *Lemna Minor* on Physicochemical Characteristics of Domestic wastewater in Reactor R1.

Time (days)	Temp ^{0}C	pH	DO mg/L	TSS mg/L	TDS mg/L	TS mg/L	BOD mg/L	COD mg/L	TN mg/L	TP mg/L	Turbidity mg/L
0	30.5	7.61	1.0	260	375	635	144.6	239.0	30.40	4.60	113.63
7	34.0	7.64	3.2	125	210	335	74.0	128.4	25.76	2.55	54.74
14	32.0	7.82	3.4	65	135	200	41.3	112.0	20.05	1.78	28.86
21	33.0	7.85	4.4	45	90	135	23.6	96.20	15.75	1.10	19.76
28	33.5	7.80	6.0	30	90	120	18.3	89.60	9.40	0.80	12.76

Table 2. Percentage reduction of pollutants in Domestic wastewater in Reactor R1.

Time (days)	%TSS reduced	%TDS reduced	%TS reduced	%BOD reduced	%COD reduced	%TN reduced	%TP reduced	%Turbidity reduced
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	51.92	44.00	47.24	48.82	46.44	15.26	44.56	51.82
14	75.00	64.00	68.50	71.44	53.14	34.04	61.30	74.60
21	82.69	76.00	78.74.	83.68	59.75	48.29	76.08	82.62
28	88.46	76.00	81.10	87.34	62.51	69.08	82.61	88.77

III. RESULTS AND DISCUSSION

The results of the analysis of domestic wastewater characteristics at an interval of every 8 days of culture of *Lemna minor* till 28 days are presented in Table 1. It showed that values of pH were in alkaline stage and ranged between 7.61 as minimum at zero day and 7.80 as maximum after 28 days of treatment. A pH of around 7.5 was found to be most ideal for optimum pond performance [5]. Sewage temperature is one of the crucial design parameters for duckweed Pond system [9]. In the present study, temperature ranged between 30.5^{0}C to 34.0^0 C, which is within the upper tolerance limit of around 34^0 C [4] for duckweed growth.

As per the results in Table 1, Total Suspended Solids (TSS) decreased by increasing the hydraulic retention time, reaching a minimum concentration of 30 mg/l after 28days in the reactor R1. Total dissolved solids (TDS) recorded the minimum value of 90 mg/l in reactor R1 after 28 days HRT. The D.O. concentration showed gradual increase from 1 mg/l initially to 6.0 mg/l after 28 days HRT in reactor R1.

As per the Table 2, B.O.D., C.O.D., Total Nitrogen (TN), Total Phosphorus (TP) showed gradual removal over a period of time. B.O.D. removal was more than 85% in the reactor whereas C.O.D. removal was more than 60%. Around 70% removal of TN was recorded in the reactor whereas the TP removal was more than 80%. 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.

According to I.S. 2296 and IS 2409-1974, the effluent standard after harvesting acceptable for agriculture and gardening use should limit BOD to 12-20 mg/l, Total Solids to 30-200 mg/l and Suspended solids to 30mg/l [12]. 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.

IV. CONCLUSION

Water scarcity currently affects many regions of the world. Without a significant reversal of economic and social trends, it will become more acute over time. Deteriorating water quality has become one of the most critical issues affecting both the developed and developing countries. Proper mitigation strategies must start immediately to meet the growing water shortage crisis. Since conventional wastewater treatment technology is energy intensive hence costly, Phytoremediation of wastewater using floating aquatic macrophyte duckweed as stripper is an attractive option particularly in areas where sunshine availability is in plenty. Duckweed is found to be efficient contaminant removal under optimum operational conditions. System is found to be simple in terms of operation & 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 water supply system can be relieved from extra demand as the wastewater reclaimed meets the reuse criteria for agriculture and gardening. System optimization studies including that of harvesting regimes are necessary to have optimum results.

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