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Study on Effect of Clay Bottomed Red soil Tank for Improving Water Quality

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Abstract: In this work, the effectiveness of duckweed in **Clay Bottomed Red soil Tank (CBRT)** for improving water quality in batch scale is studied. The physico chemical properties are analyzed and it is found that the sewage treated in **CBRT** is meeting the disposal standards. The removal of Total Dissolved Solids (TDS) is more effective during the initial 2 days and then the rate of removal is slowdown due to accumulation of pollutants on plant leaves. After four days, the dissolved substances return back into the water from plants due to saturation of plants[1]. Therefore four days hydraulic residence time is enough for treatment of sewage in CBRT. Nutrients are taken up by plants throughout the experimental period. The clay layer at the bottom soil creates appropriate environment for the plants to grow healthier and hence it is recommended to use clay layer to increase the efficiency of the system.
Keywords: Sewage, Clay Bottomed Red soil Tank (CBRT), Duckweed, Pollutant Removal.

Introduction

Due to rapid population growth, urbanization and industrialization, a huge volume of waste water is generated leading to serious worldwide water crisis[5]. The waste water is discharged into natural water bodies and land resources without proper treatment. Due to continuous unsafe disposal of waste water, the water bodies lose their self-purification capability. Also, disposal of waste water into land causes ground water pollution. Conventional waste water treatment is too expensive and difficult to implement at all the places[21]. Insufficient funds are also a reason for not implementing the waste water treatment plants in all parts of the country. For small communities and industries, low cost simple waste water treatment methods are more appropriate[17,27]. Macrophyte based waste water treatment method secures to be a potential method[5,16, 24].

Macrophytes are generally free floating, emergent or submerged plants[21]. Most of the earlier researches have discussed the effectiveness of plants for treatment of waste water[1, 3,4,9,11,12,13,14,17,19].

The commonly used aquatic plants for water treatment are duckweed, water hyacinth, azolla, salvinia molesta etc. The Lemnaceae family consists of four genera (Lemna, Spirodela, Wolffia, Wolffiella) and 37 species[29]. Several Studies have been conducted to improve the water quality using duckweed plant[1,3,4,7,8,10,13,16,17,18,28]. The dissolved oxygen level is more in experimental pond containing duckweed[3,4]. The duck weed takes a lag period of 96 hours for its growth[13].The effect of circulation in Lemna gibba and Lemna minor treatment unit gives better performance than without circulation in urban sewage[8]. The waste water from duckweed- microalgae constructed wetland can be reused in the agricultural domain[17].The effect of glyphosate toxicant on the growth rate of duckweed is studied[26]. In duckweed treatment unit, fecal coliform removal is 95% [18].

Water hyacinth is a broad leaved aquatic plant commonly used for waste water treatment[3,6,12,14,20,21,27,29]. The uptake of nutrients by water hyacinth in municipal waste water is fast for the first two days is confirmed[14]. The water hyacinth is more efficient in utilizing NH_4^+ source than Nitrate, Urea and digester effluent[20]. The uptake of heavy metals by water hyacinth was dependent upon the concentration of the metal and the duration of the exposure[12]. The feasibility of using water hyacinth for removal of lead and zinc from pulp and paper mill effluent is discussed[27].

Azolla is a promising candidate for phytoremediation is concluded[5]. Azolla grown well in partially treated sewage than diluted pig wastes[15]. The potential use of free water surface flow system with the option of circulation improves urban sewage water quality [29].

The Phragmites communis emergent macrophyte shows high capability to accumulate trace metal in roots than Najas marina submerged macrophyte plant[9]. T.domingensis is good when there is high pH; EC in industrial waste water[11]. Channel grass is good for treating pulp and paper mill and distillery effluents [22].

In our previous studies[4, 26], the experiments were conducted in plastic tanks without soil bottom, wherein the sediments got deposited at bottom and created anoxic and unhealthy condition.

In the present work, an attempt has been made for simulating natural pond bottom conditions in the laboratory for making suitable condition for plants as in natural environment. For this purpose, the clay soil is placed at the bottom of a red soil tank and the effectiveness of using clay soil for the improvement of water quality was studied.

Materials and Methods

The experimental tank (0.25m x 0.25m x 0.30m) is constructed using red soil with cementitious coating. The bottom of the tank is covered with 2 cm thick clay soil paste (clay layer) and it is dried in sunlight for 3 days. The sewage is collected from outlet of screening tank in Kalasalingam University sewage treatment plant, Krishnankovil, located at Virudhunagar district, Tamil Nadu. First, 16 liters of sewage was introduced into the tank. The initial parameters of the sewage such as pH, Temperature, Dissolved oxygen, Turbidity, Nitrates, Orthophosphate, Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) are analyzed and recorded. Fresh healthy duckweed plants found near Srivilliputhur, located at Virudhunagar district, Tamil Nadu was collected and cleaned with distilled water for removing the impurities. 10 g of fresh duckweed was introduced in the experimental tank and the water quality parameters were precisely analyzed from day 1 to day 6.

Water Quality Testing

Various water quality parameters of the sewage are analyzed using standard methods as follows: TDS and TSS were analyzed by gravimetric method, pH was measured by pH electrode method, Turbidity was measured by digital turbidity meter method, Dissolved oxygen (D.O) was measured by Winkler's method, Nitrates was determined by Brucine sulphate method and Orthophosphate was determined by Ammonium molybdate method [23]. Table 1 shows the characteristics of preliminary treated effluent from sewage treatment plant.

Table 1: Physico Chemical Characteristics of sewage of Preliminary treated sewage

S No	Parameters	Values
1	pH	6.52
2	Temp ºC	30
3	Turbidity(NTU)	175
4	D.O (mg/l)	1.44
5	TSS (mg/l)	1462
6	TDS (mg/l)	1538
7	TS (mg/l)	3000
8	Orthophosphate (mg/l)	4.2
9	Nitrates (mg/l)	32.33

Soil Testing

The clay soil used for making bottom layer is also was tested before and after experiment, in the Tamilnadu Government Agricultural and Soil Testing Centre, Virudhunagar.

Results and Discussion

On physical observation, it was found that the sewage color and bad odour had totally disappeared within a week of treatment in the duckweed experimental pond. In CBRT tank no algae was found throughout the experimental period. Hence odour became nil[28].

The pH of duckweed based wastewater treatment unit has increased from 6.52 to 8.6. This is mainly due to the following reasons (i) increased decomposition of organic matter, which in turn produced excess carbon dioxide in sewage resulting in an increase of pH[28]. (ii) increased soluble ions present in tank during evaporation (iii) due to photosynthetic activities of plant[3]. Also it was observed that the temperature of duckweed experimental pond fluctuated between 26°C to 30°C. After two days temperature is constant in experimental pond.

The dissolved oxygen level is found to increase from 1.44mg/l to 3.52 mg/l which can be attributed to atmospheric diffusion; the supply of oxygen by duckweed plants to the treatment unit is more than the consumption of dissolved oxygen by microbial activities for decomposition and respiration activity by the duckweed plants[3,4].

Turbidity level has decreased from 175 NTU to 45.4 NTU, which is due to sedimentation and adsorption of pollutants on plant leaves.

The TDS has increased from 1538 mg/l to 2051 mg/l on the first day of experiment. The possible reason for higher amount of TDS might be more dissolved minerals present in clay soil. The Total Dissolved Solids (TDS) decreased from 1538.4 mg/l to 278mg/l at fourth day; however on fifth day onwards TDS started to increase again. This may be due to the following reasons (i) increase of plant growth and decay, enhanced evaporation and transpiration, releasing higher TDS values[2,28] (ii) The plants might have released the accumulated ions again into the water[1].

Total Suspended Solids (TSS) has continuously starting to end of the experiment from 1461mg/l to 157mg/l at the end of the experiment[28]. This is due to sedimentation of solid particles.

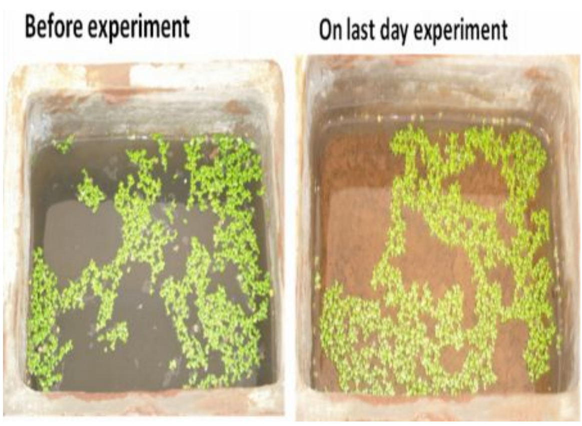


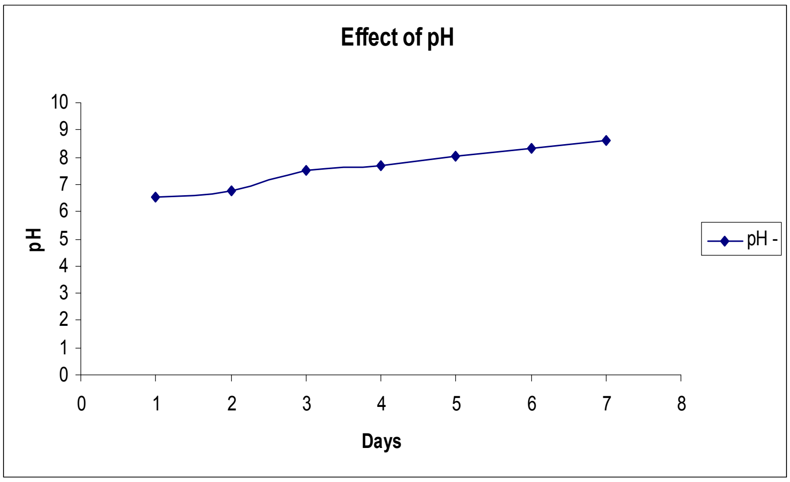
Fig.1 Before and After treatment in CBRT unit.

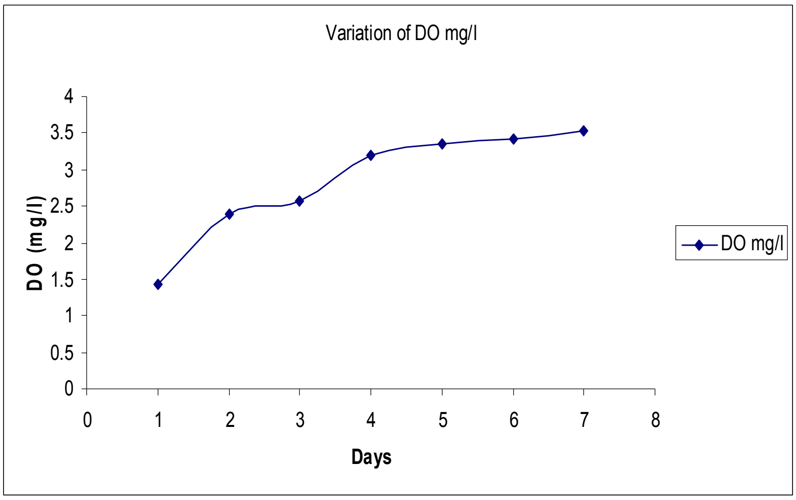
The Total Solids (TS) decreased from 3000 mg/l to 500 mg/l from the first day till fourth day; however the Total Solids (TS) has increased to 1251 mg/l on fifth day. This can be attributed to high amount of dissolved solids present in the system. Therefore, four day hydraulic residence time is effective for removing Total Solids (TS). The water quality in CBRT with duckweed unit is shown in Table 2 & Fig .1 shows before and after treatment of sewage in CBRT with duckweed based unit.

Table 2: Physico Chemical Characteristics of Sewage in Clay Bottomed Red soil tank with duckweed treatment unit

Parameters	Before treatment	After treatment					
		Day1	Day2	Day 3	Day 4	Day 5	Day 6
pH	6.52	6.78	7.54	7.70	8.05	8.30	8.60
Temp °C	30	27	28	26	26	26	26
D.O (mg/l)	1.44	2.40	2.56	3.20	3.36	3.42	3.52
Turbidity (NTU)	175	93.8	55.5	51.8	45.8	45.8	45.4
TDS (mg/l)	1538	2051	555	555	278	1050	1143
TSS (mg/l)	1462	449	445	445	222	201	157
TS (mg/l)	3000	2509	1000	1000	500	1251	1350
Ortho phosphate (mg/l)	4.20	2.23	2.15	1.50	0.73	0.63	0.48
Nitrates (mg/l)	32.33	64.89	40.56	16.62	6.64	4.20	3.65

Pollutant removal efficiency





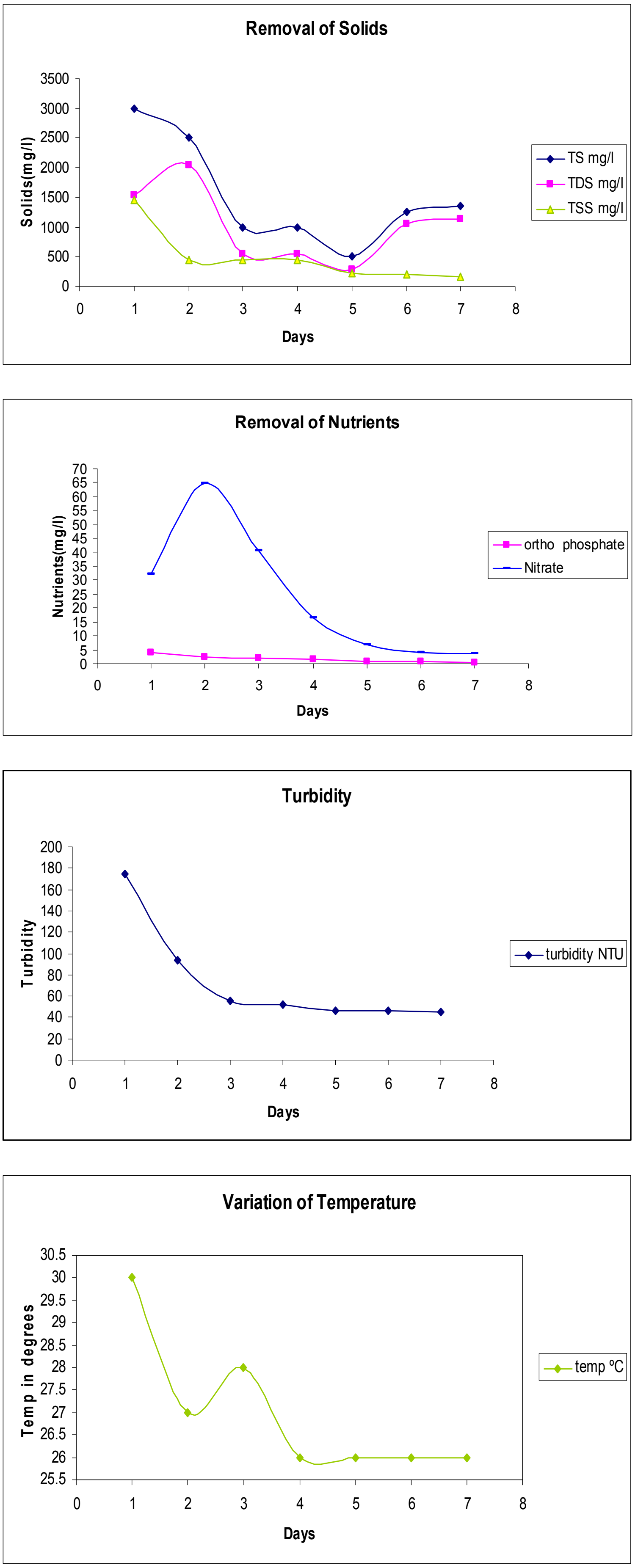


Fig.2: Water quality variation in CBRT

The percentage removal efficiency of waste water quality variables were calculated using the following formula = (1- *Cf/Ci*) x 100% where *Cf* = concentration of the pollutant after treatment, *Ci* = concentration of the pollutant before treatment[16]. Fig.2 shows water quality variation in CBRT based duckweed unit. The dissolved oxygen level in the experimental tank increased by 59% compared to the initial day. From Table 3 we can conclude that the percentage of pollutant removal rate is high for the first two days, then it slowdown due to accumulation of pollutant particles on duckweed leaves[1]. After fourth day, the plants become ineffective for removal of pollutants due to saturation of pollutants on plants. The efficiency of macrophyte system depends upon periodic harvesting of biomass produced and the harvesting time [6,19,25]. So it is recommended to harvest one fourth cover of duckweed every four days[25] due to the following reasons (i) To provide space for new growing plants for effective atmospheric diffusion of air into the system.

(ii)To avoid deposition of old, dead duckweed leaves into the system (iii) To avoid leaching back of pollutants from plants into the water[1].

At the end of the experiment, the wet weight of duck weeds has increased from 10g to 16g due to high Phosphorous and Nitrogen level in sewage[13]. Duck weeds biomass can be used as fish feed[10]. Fresh duckweed can completely replace soya bean, broken rice[7] as a food item.

Table 3: Percentage removal of pollutants in Clay Bottomed Red soil tank with duckweed treatment unit

S.No	Parameters	Percentage removal of pollutants					
		Day1	Day2	Day 3	Day 4	Day 5	Day 6
1	Turbidity (%)	46.40	68.28	70.40	73.83	73.83	74.05
2	TDS (%)	-33.00	63.91	63.91	81.92	31.73	25.68
3	TSS (%)	69.29	69.56	69.56	84.82	86.25	89.27
4	TS (%)	16.37	66.67	66.67	83.33	58.3	55.00
5	Ortho phosphate (%)	46.90	48.81	64.29	82.61	85.00	88.57
6	Nitrates (%)	-100.70	-25.5	48.59	79.46	87.01	88.71

Nutrient Removal

The Nitrate has increased from 32.33mg/l to 64.89mg/l on the first day of the experiment, which is due to nutrients present in clay soil and decomposition of organic matter. However, the nitrate level at the end of sixth day is 3.65 mg/l, which may be due to consumption of nitrates by duckweed plants for its growth[3, 24]. Orthophosphate value has decreased from 4.2 mg/l to 0.48 mg/l which is due to uptake by duckweed plants and assimilates into plant protein, chemical precipitation, adsorption on plant leaves and microbial uptake[3]. Regular harvesting may increase phosphate removal[3].

Effect of clay bottom

The properties of soil used for making clay layer at the bottom of the experimental tank are given in Table 4. The clay layer and its high nutrients enhance more biological activities within the system. The sediments deposited at bottom are also decomposed by the presence of microbial layer in clay layer. Additionally, the bottom clay soil can also be removed occasionally and used as manure.

Table 4: Properties of Clay soil

Parameters	Before expt	After expt
pH	7.3	7.9
Electrical Conductivity (ds/m)	0.8	0.8
Nitrogen(g/m^2)	35.7	24.5
Phosphorous (g/m^2)	5.61	5.61
Potassium (g/m^2)	26.1	117.5
Iron (mg/l)	2.1	2.3
Manganese(mg/l)	3.1	3.3
Zinc(mg/l)	0.8	0.7
Copper (mg/l)	0.9	0.8

Effect of material used for experimental tank

Comparing our previous studies[26] the new experimental tank made of red soil removes pollutants more effectively due to the high oxygen transfer capacity through its surface. The sewage becomes cooler and produces high dissolved oxygen inside the experimental tank[28].

Conclusion

In this project, the effectiveness of *Clay Bottomed Red soil Tank (CBRT)* with duckweed plant unit for improving water quality in batch scale was analyzed. From the observation, in CBRT pollutant removal is fast for the first 2 days, thereafter the pollutant removal rate slowdown due to the saturation of pollutants on duckweed plants[1, 17]. In this experiment, due to presence of clay layer, the plants grow healthier and they are effective and efficient in the treatment of waste water. From the observations we conclude that (i) Materials used for making treatment unit also have an impact on the water quality. (ii) Providing clay soil at bottom helps to improve water quality.

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