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Evaluation of lab scale constructed wetlands to treat the toddy distillery effluent with different aquatic plants

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ABSTRACT

Effluent 'Coda' originating from palmyrah toddy distillery units is the major source of environmental pollution in the Jaffna district of Sri Lanka. Spent wash produced from distilleries is rich in organic material and characteristically less toxic. The study was aimed to assess the potentiality of constructed wetlands for treating of distillery spent wash in lab scale with various configurations treatments, before discharge to the land. Effluent was collected from Thikkam distillery in Jaffna. The effluent was diluted with groundwater as different series. The aquatic plants, Eichhormia sp, Lemna sp, Pistia sp and Lemna minor sp were selected. Constructed wet land was designed and fabricated in lab scale. Initial parameters of the effluent were measured. Samples from inlet and outlet of the artificial wetland were collected on two days interval for one week and analyzed for pH, BOD, COD, Turbidity, NO_3^-, PO_4^{3-}, *TDS, and EC using standard methods with replicates with hydraulic retention time of 2, 4, and 6 days. Even diluted effluents were often above the permissible standards specified by the Central Environmental Authority for the discharge of industrial effluents into land. The aquatic plants Eichhormia sp, Lemna sp, Pistia sp and Lemna minor were used successfully to treat the spent wash .Complete death of Pistia was observed in dilution of five. Constructed wetlands were successfully removed TDS, nitrate, phosphorus, BOD, COD, turbidity, EC, and change the pH. The maximum removal rates of EC, TDS, COD, BOD, nitrate, and phosphate in constructed wetland were 50.14%, 48.42%, 45.5%, 56.3%, 35.3%, and 54% respectively. It was found constructed wetland shows highly significant removal efficiency of all tested components by Lemna minor . The hydraulic retention time of six days was showed the highest removal efficiency and maximum reduction rate of all the tested components. But hydraulic retention time of four days which is more possibility to keep, because the values of constituents of distillery waste are moreover reached the permissible standards specified by the CEA to discharge to land or irrigation. After treated effluent through, construction of wetlands could be use as a liquid fertilizer for cultivating field.*

Keywords: Distillery effluent, Constructed wetland, Dilution factor, hydraulic retention time, Removal efficiency

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INTRODUCTION

Waste is unwanted or discarded material resulting from agricultural, commercial, and industrial activities. Waste generation rate in the society is increasing with an increasing population, technological development, and the changes in the life styles of the people [1]. The generation of waste has become an alarming environmental and public health problem all over the world, especially in developing countries. The common practices in almost all municipalities in Sri Lanka are open burning, land filling, and open dumping. These methods are not considered as environmental friendly since they create serious environmental problems. About 85 % of collected waste in Sri Lanka is subjected to open dumping. Sri Lanka faces a number of water and wastewater issues and water related health hazards [2]. The large cities such as Colombo, Galle, Jaffna and Kandy have serious problems such as disposal of sewerage, industrial effluents and industrial and domestic solid waste, as they generate large quantities, but have no facilities for their treatment and proper disposal [3].

A large and increasing volume of wastewater is produced globally by the winery and distillery industries [4]. Considerable amount of waste water is coming from distillery units which are situated in Jaffna at Navally and Thikkam. In the Northern part of Sri Lanka, especially in the Jaffna peninsula, the distilleries are using, naturally fermented palmyrah and coconut sap called ‘palmyrah toddy’ and ‘coconut toddy’ respectively to obtain ethanol.

This distillery unit generates 1.3 million liters of effluent annually and the principal waste is locally referred as “Coda”. The fresh acidic spent wash produced from the distilleries are of high in temperature and have high Biological Oxygen Demand (BOD), large amount of suspended solids and high turbidity. In a developing country like India, distillery industries have become a major source of pollution, as 88% of its raw materials are converted into waste and discharged into the water bodies causing water pollution [5]. The disposal of large quantities of biodegradable waste without adequate treatment results in significant environmental pollution. More than 90% of wastewater in the developing countries is discharged directly into rivers, lakes, and coastal water without any treatment. The values of constituents of distillery waste are often above the permissible standards specified by the Central Environmental Authority for the discharge of industrial effluents into inland water bodies. Discharge of untreated acidic spent wash can destroy aquatic organisms. As well as higher amount substances, heavy metals and toxic compounds present in the waste water pollute the natural fresh water which is the prime source for agricultural and animal production.

Distillery wastewaters vary throughout the world, as a result of the different raw materials used to produce ethanol [6]. Generally, distillery wastewaters are high in organic load and low in pH. Several criteria should be considered when selecting a treatment system for wastewaters. These include an eco-friendly process that is flexible enough to handle variable organic and volumetric loads, low capital and operating costs, and minimal maintenance and footprint, while still providing the desired degree of degradation without the need for wastewater dilution with potable water [7].

Since there is no any well sound management technique available up to now in distilleries, potential effluent is discharged into the deep sea without treatment at Thikkam. Construction of wet land to treat effluent is the best approach practiced in developed countries. Moreover, constructed wetlands can also be a cost-effective and technically feasible approach for treating wastewater. Wetlands are often less expensive to build than traditional wastewater treatment options, have low operating and maintenance expenses and can handle fluctuating water levels. Hence the objective of the study was seeking the solution through construction of low cost wet lands to remove pollutants from distillery spent wash.

MATERIALS AND METHODS

2.1 Collection of toddy distillery spent wash

Effluent was collected from Thikkam distillery in Jaffna. Fresh effluent samples were collected directly from the out let without accumulating in aerobic tank into 20 liter plastic containers for further analysis. The temperature of distillery spent wash was at 85^{o}C while discharging to the out let point.

2.2 Determination of optimal dilution factor

Important chemical properties such as pH, dissolved oxygen (DO), Electrical conductivity (EC) and total dissolved solid (TDS) of fresh effluent were measured by respective meters to identify the problematic parameter and to determine the dilution factor. The effluent was diluted with groundwater and got different dilution factor. The following aquatic plants, *Eichhormia sp, Lemna sp, Pistia sp and Lemna minor* were selected for research study on the basis of their fast growing habit in waste water and high nutrient feeding. Then selected four aquatic plants of same age group were cleaned, and placed to grow in each dilution series in opened plastic water bottles. It was kept at natural environment.

2.3 Experimental set up

The artificial wet land was designed [8]. Proper dimensions of rectangular fiber glass tank (Figure 01) were used. The effluent was allowed for the sedimentation in the sediment tank for one day. After that effluent was collected from the upper region of the sediment tank. Then it was aerated by using air compressor for one hour. Again effluent was adjusted to the pH 6 by using lime. After the improvement by aeration and lime application, the dilution factor was decreased to ten times from twenty times. After that in proper designed wet land, further dilution of five times was satisfied to the aquatic plants. All the research was continued with five times dilution factor. Selected aquatic plants were randomly assigned into five treatments (To - T_4) as follows:

To	Control
T_1	*Eicchormia*
T_2	*Lemna minor*
T_3	*Lemna*
T_4	*Pistia*

At the same time control was maintained as treated effluent and fresh effluent were kept as without plant to get the effect of plant on the removal of substances. Samples from inlet and outlet of the artificial wetland were collected on two days interval for one week with hydraulic retention time of 2, 4 and 6 days and analyzed in replicates for pH, BOD, COD, Turbidity, Nitrate (NO_3^-), Phosphate (PO_4^{3-}), TDS, and EC using standard methods. The experiment was done in CRD and analysized with SAS package. The mean separation was done by using Dunnett and Duncan method.

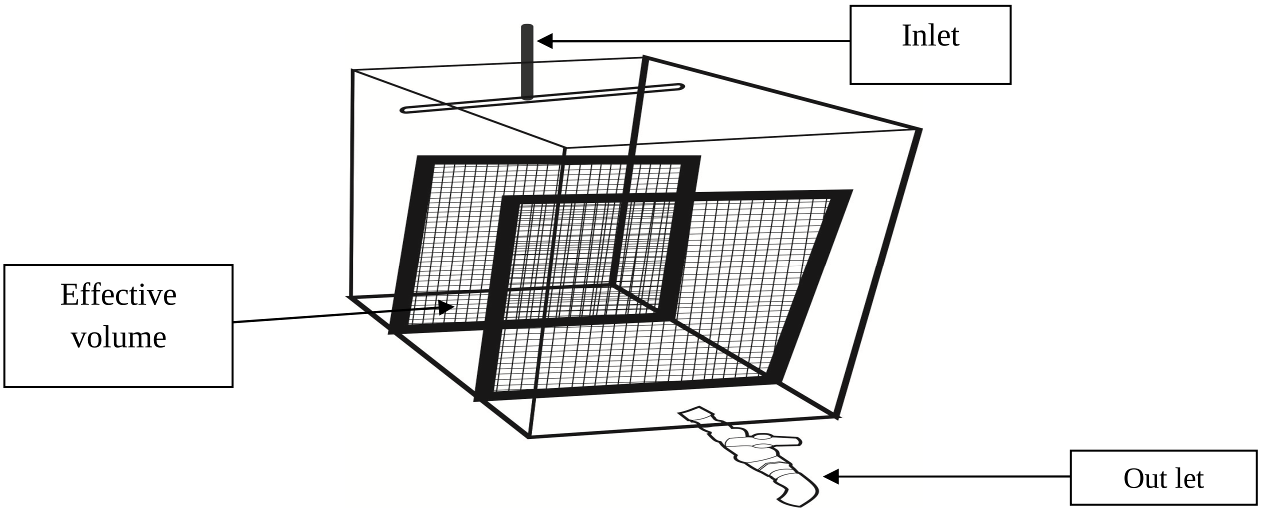


Figure 1: Schematic diagram of designed artificial wet land

2.4 Selection of aquatic plants

All wetland species are not suitable for wastewater treatment since plants for treatment of wetlands must be able to tolerate the combination of continuous flooding and exposure to wastewater or storm water containing relatively high and often variable concentrations of pollutants. Choosing the species of vegetation is very important in constructed wetlands. Ideally, constructed wetlands for treating wastewater need to be as versatile and easily maintained as possible. *Eichhornia* Sp can withstand with water depths up to 45 cm and fast growing plant in fresh water and also it holdup high nutrients levels and tolerate drought conditions for several weeks [9]. Therefore, *Eichhornia* sp was included with other sp of *Lemna* sp, *Pistia* sp and *Limnocharis* sp. Floating plants is distinguished by the ability of these plants to derive their carbondioxide and oxygen needs from the atmosphere directly. The plants receive their mineral nutrients from the wastewater.

RESULTS AND DISCUSSION

3.1Phosphate Removal in constructed wet land

Nitrogen and phosphorous are two main nutrients found in wastewater in high quantities. High levels of phosphorus in effluent can also cause eutrophication in water bodies. Phosphorus is present in the wastewater in the form of orthophosphate and organic phosphorous, which is found in the wetlands as part of sediments [10]. Adsorption is the most important phosphorus removal process in the wetlands. Adsorption of phosphorus occurs due to reactions with calcium present in sediments. constructed wetlands are capable of removing N and P by treating wastewater [11]. Growing plants take up nutrients like phosphorus, thereby reducing levels in the wetland.

Phosphate values were measured at the in inlet and outlet of the constructed wetland with the different treatments and removal efficiency was estimated and shown in table 1. It was found that, *Lemna minor* shows higher removal efficiency compared to others. After two days the removal rates of PO_4^{3-} in constructed wetland were 0.90%, 25.34%, 43.25%, and 28.03 %, respectively for control, *Eichhornia* sp, *Lemna minor* and *Lemna* respectively.

Table (1) Removal efficiency of Phosphate

Treatment	Phosphate removal rate (%)		
	After 2 days	After 4 days	After 6 days
Control (T0)	0.90[c]	2.10[d]	3.453[d]
Eicchornia (T1)	25.347[b]	28.33[c]	36.24[c]
Lemna minor (T2)	43.257[a]	51.03[a]	53.44[a]
Lemna sp (T3)	28.03[b]	33.87[b]	39.26[b]

The means with the same letter were not significantly differ at α = 0.05 level

Removal efficiency of phosphate was significantly differ ($p < 0.05$) in *Lemna minor*, *Lemna* and *Eicchornia* compare from control after six days. The highest removal efficiency was observed in *Lemna minor* followed by *Lemna* and *Eicchornia.* Complete deaths of *Pistia* plants were observed after two days for the dilution of five due to the lower pH and dissolved oxygen value. It couldn't tolerate this unfavorable condition. Phosphate ions of the dilution effluent were increased in *Pistia* placed in wetland due to denature of the protein which was found in *Pistia.*

3.2 Removal efficiency of nitrate.

In wetlands, the nitrogen removal process starts with the nitrification. Denitrification occurs under anaerobic conditions and in the presence of organic matter. The N formed from denitrification is released in to the atmosphere in the form of nitrous oxide, thereby removing nitrogen from the wetland system. Denitrification is effected by factors like absence of oxygen, temperature, pH, availability of carbon source, nitrate availability, hydraulic load and hydraulic retention time [12].Nitrogen in wetlands can also be removed by nutrient uptake of plants. The plants uptake nitrogen in the form of ammonium or nitrate, which is then stored in the plant in the organic form. The uptake capacity of nitrate can vary with plant species in constructed wetlands.

Table 2 shows the nitrate removal efficiency with various retention times to different types of plants. *Eicchornia*, *Lemna minor*, and *Lemna* were influenced on nitrate removal from the effluent. Table 2 illustrate that removal of nitrate was statistically significant ($p<0.05$) compared to control. Removal of nitrate was highest in *Lemna minor*, *Lemna* and *Eicchornia* respectively. In this dilution the highest reduction of PO_4^{3-} and NO_3^- was achieved by *Lemna minor*.

Table (2) Removal efficiency of nitrate

Treatment	Nitrate removal rate (%)		
	After 2 days	After 4 days	After 6 days
Control (T0)	2.222[c]	3.5476[d]	3.670[d]
Eicchornia (T1)	10.740[b]	15.059[C]	15.6173[c]
Lemna minor (T2)	19.111[a]	33.0893[a]	34.3148[a]
Lemna sp (T3)	11.870[b]	18.5417[b]	19.2284[b]

The means with the same letter were not significantly differ at α = 0.05 level

3.3 Reduction rate of BOD

Organic pollutants include biological and chemical oxygen demand and are interrelated with the amount of Dissolved Oxygen (DO). DO is an important parameter in water quality assessment and reflects the physical and biological processes prevailing in the water bodies [13].The concentration of DO in raw effluent sample was very low as less than one. An important improvement in the quality of effluent was observed in terms of DO with subsequent increase in hydraulic retention time until it reached the maximum up to 5 mg/l in the final treatment of hydraulic retention time of six days. One of the reasons for increased DO in the vegetative units of the constructed wetland might be the biodegradation of compounds present in wastewater that previously used dissolved oxygen for various oxidation reduction reactions and thus the release of oxygen through roots.

Table (3) Changes in BOD.

Treatment	Changes in BOD		
	After 2 days	After 4 days	After 6 days
Control (T0)	41.00[d]	54.02[c]	65.23[c]
Eicchornia (T1)	477.33[c]	692.00[b]	887.13[b]
Lemna minor (T2)	859.33[a]	1012.33[a]	1546.32[a]
Lemna sp (T3)	490.66[b]	669.33[b]	865.37[b]

The means with the same letter were not significantly differ at α = 0.05 level.

The untreated (raw) wastewater had high range of COD and BOD_5 17540 and 25576 mg/l respectively. These high values were due to the presence of large amount of organic compounds in the distillery wastewater. Maximum activity was observed with six day hydraulic retention time where both COD and BOD values were reduced up to

1350 –1500 and 1800-2240mg/l. It also found COD and BOD_5 removals of 45 and 56.3%, respectively, with retention time of six days.

Table 4 shows that reduction of BOD was statistically significant ($p<0.05$) in *Lemna minor* compared to control. BOD reduction was highest in *Lemna minor* within retention time of six days. Because , *Lemna minor* (Duckweed) is all particularly well suited to taking up and storing nutrients and duckweed can more-than-double its biomass in two days.

Reduction rate of COD.

Reductions of COD on effluent were varied with type of treatment. Results revealed that reduction of COD were statistically significant in *Eicchornia*, *Lemna minor,* and *Lemna* This decrease in COD values might be due to high biodegradation of organic contaminants of wastewater during constant biological activities in the plants having dense root hair structure .

Table(4) Changes in COD

Treatment	**Reduction of COD**		
	After 2 days	After 4 days	After 6 days
Control (T0)	63.14[d]	99.36[c]	140.5[c]
Eicchornia (T1)	735.09[c]	1273.28[b]	1907.8[b]
Lemna minor (T2)	1323.37[a]	1862.69[a]	3324.6[a]
Lemna sp (T3)	755.62[b]	1231.57[b]	1861.2[b]

The means with the same letter were not significantly differ at α = 0.05 level

Changes of TDS and EC.

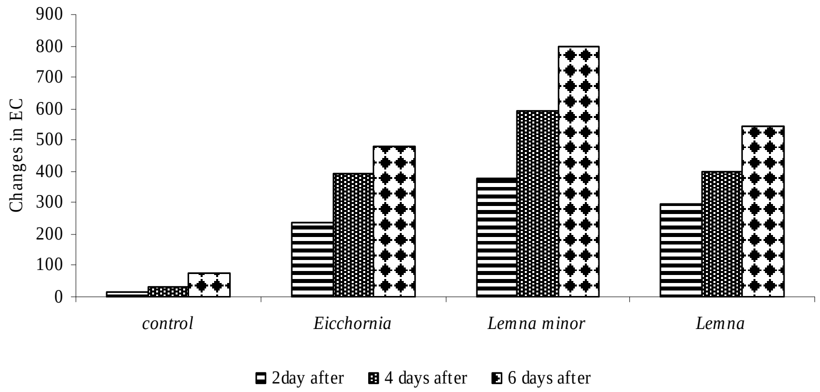


Figure (2) changes in EC with different treatments

The value of EC and TDS were found to be 3.5-4.5µS/cm and 1800-1950mg/L, respectively, in diluted with water as five times. It was found that EC value of diluted effluent was decreased gradually during treatment due to the decrease in TDS .EC is directly dependent on the suspended and dissolved solids [14]. This decrease in EC might be related to the conversion of NO_3^- into diatomic molecular nitrogen (N_2), which also decreases EC levels of effluent, which was 854mS/cm (50.14%) with hydraulic retention time of 4 days. Figure 4.3 and 4.4 show the EC and TDS concentration reduced with hydraulic retention time of 2, 4, and 6 days in different treatments.

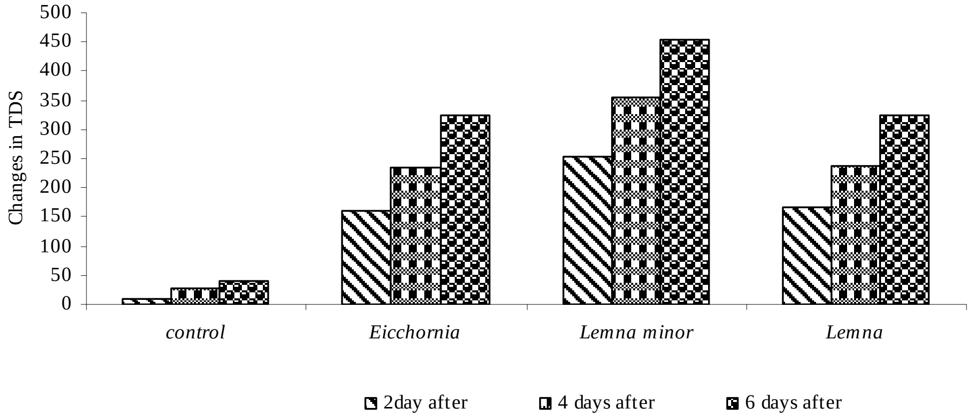
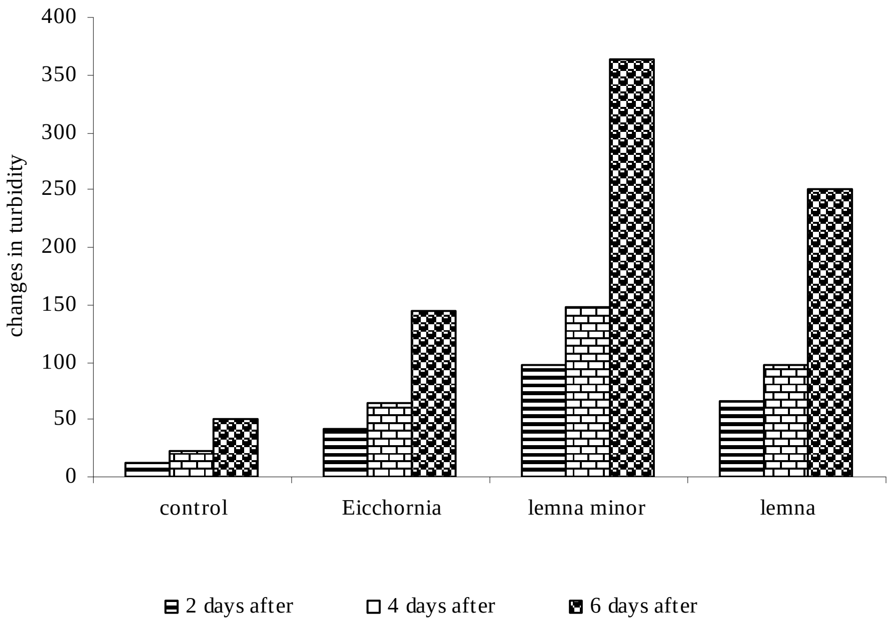


Figure (3) changes in TDS with different treatments

Odour and pH.

Among physical parameters, odour is very important for the determination of water quality. In the present study, the effluent had unpleasant and penetrating smell. According to WHO standards, the clean water should be free of any type of odour. The notable mineralization of the organic substances and removal of microbes during various treatments in the constructed wetland resulted in the reduction of odour. In addition, pH value of constructed wetland should be above 6 in order to achieve an efficient denitrification activity [15]. Throughout the experimental period the pH of the treated wastewater remained within a range of 7.05–7.91.



Figure(4)Changes in turbidity with different treatments

Table : 5 Value of parameters changing with different hydraulic retention time for *lemna minor*

Parameters	Environmental recommended	Hydraulic retention time		
		Two days	Four days	Six days
pH	5.5 - 9.0	6.26	6.45	6.74
BOD (mg/l)	250	2451	1847	1325
COD (mg/l)	400	5324	2845	2214
TDS (mg/l)	2100	2758	2089	1965
EC (mS/cm)	2.25	2.453	2.345	2.18

Table 5 shows value of parameters changing with different hydraulic retention time for *lemna minor*. The hydraulic retention time of six days was showed the highest removal efficiency and maximum reduction rate of all the tested components. But hydraulic retention time of four days which is more possibility to keep, because the values of constituents of distillery waste are moreover reached the permissible standards specified by the Central Environmental Authority to discharge to land or irrigation. Further the designed constructed wetland was with stagnation wastewater but actual wetland in the field is running wastewater condition. In the particular situation inflow and outflow could be controlled by inlet and outlet valve respectively.

CONCLUSION

Recent research has focused on using constructed wetlands to treat distillery wastewater. The contaminants being removed include suspended solids, nitrate, phosphorus, BOD, COD, turbidity, EC, and change the pH. Research has found that wastewater wetlands are successful in removing contaminants but sometimes may not be the best option for primary treatment standards. Constructed wetlands make a good secondary method for treating distillery wastewater. Constructed wastewater wetlands offer aesthetic pleasing environments which function on less complicated technologies that are successful in removing many different types of contaminants.

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REFERENCES

[1] K.Sivakumar, M.Sugirtharan, *J Sci.Univ.Kelaniya* ,**2010**, 5, 13-23.
[2] M. Sudasinghe, L.Galagedara, E.Gunawardena, *Tropical Agricultural Research* **2011**, 22, 2, 741–748.
[3] N.J.G.J Bandara, *Water Sci. and Technol*, **2003**,12, 305-312.
[4] K. L. S. Peter, International Conference on Environment and Health, Chennai, India, **2008**, 15-17.
[5] A. Farid, K. Awasthi, P. Ajay, N.Mishra, *International Journal of Applied Environmental Sciences*, **2010**, 5, 5, 741–748.
[6] A. Farid, K. Awasthi, P. Ajay, N.Mishra, *International Journal of Applied Environmental Sciences*, **2010**, 5, 5, 741–748.
[7] K. L. S. Peter, International Conference on Environment and Health, Chennai, India, **2008**, 15-17.
[8] A.Yasotha, L. Galagedara, M.Mowjood, Water professionals's day symposium Oct.**2007,** 52-61.
[9]K. Sujatha, N. DhaneshGunatilleke, J .Mahesh, C. Nanayakkara, National conference of water convention,**2013**,Sri Lanka .
[10] M.Sundaravadivel, S. Vigneswaran, *Critical Reviews in Environmental Science and Technology,* **2001**, 31, 4, 351–409.
[11] K.Sakadevan, H.J. Bavor, *Water Science and Technology,* **1999,** 2, 40,121-128.
[12] S.Bastviken, Dissertation ,Linköping University(Sweden,**2006**).
[13] K. Sathish, G. Melchias, P.Saravanan, M. Elizabeth, *International Journal of Recent Scientific Research*, **2013**, 4, 3, 290-293.
[14] N.Musee, L. Lorenzen, C.Aldrich, *Environmental Progress*, **2006**, 25, 56–63
[15] J.T. Verhoeven, F.M. Meuleman, *Ecological engineering*, **1999**,12, 5-12.