STUDY ON AN INTEGRATED CONSTRUCTED WETLAND SYSTEM FOR COLOUR REMOVAL OF TEXTILE DYEING EFFLUENT

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ABSTRACT

Textile dyeing effluent contains various types of azo-dyes which are not 100% bio degradable. In addition to that, different types of chemicals, surfactants and various types of additives are also present in the effluent. Due to the higher concentration of colour in the dyeing effluent, it is impossible to discharge effluent into the environment. Studies have been carried out to remove COD, BOD and dissolved solids via constructed wetlands. However there is no significant study done on colour removal of textile dyeing effluent via wetlands. Thus, the main aims of this study are to design and test a suitable integrated constructed wetland system to remove colour from the textile dyeing effluent and to investigate the effect of using different plant species. Three integrated pilot units were set with different operating conditions. The first unit consists of two subsurface flow sub-units with the plant *Typha latifolia* (cattails) and a free water surface unit with *Lemnaceae*(Duckweed). The second unit contains two subsurface flow units without plants to find the effect of the material used as the bed and a free water surface unit without plants. The third unit consists of two subsurface flow units with the plant *Typha latifolia* (cattails) and the free water surface unit with *Hydrilla verticillata* (Hydrilla). Starting from a single day, the resident time was gradually increased up to 4 days where 90.87% colour removal was achieved. Hence industrial wastewater was fed into the process with a flow rate of 8.0 l/day at a retention time of 3 days. The measured parameters were pH, Dissolved Oxygen, Chemical Oxygen Demand (COD), Suspended Solids and Colour. Influent and effluent from each unit were sampled and analysed for colour using the absorpmetric method. The experiment was carried out for a total period of thirty-nine days. The units with plants showed a significant colour reduction compared to the unit without plants. During the start-up phase of the experimental set up a significant amount of colour removal of 60-70% was observed but there were small deviations due to the accumulation of colour in the root system of duckweed. After that, when the system reached a stable status, the percentage colour removal of 95-98% was achieved using the units with plants. Furthermore, the third unit in which the free water surface consists of Hydrilla verticillata (Hydrilla) showed the highest rate of colour removal of 97.8%. Thus, cattails increased the colour removal in the subsurface flow unit. It can be concluded that the colour of the textile dyeing effluent could be removed using the integrated constructed wetland system where the free water surface consists of *Hydrilla verticillata* (Hydrilla).

Keywords: *Constructed wetland, textile dyeing effluent, colour removal*

1. INTRODUCTION

The textile dyeing industry produces large amounts of wastewater that typically contains a variety of dyes and associated chemicals. The discharge of coloured effluent into the environment is undesirable. Azo dyes are commonly used for dyeing and they are not biodegradable. It is also difficult to degrade the azo dyes using biological and chemical processes due to the complexity in their structures [1, 2].

The common methods used for textile wastewater treatment include coagulation, flocculation, oxidation, membrane separation and adsorption. However, even using these methods, it is impossible to achieve the expected quality of wastewater to be discharged to the environment. Constructed wetland is a manmade wetland created as a new or restored habitat for native and migratory wildlife, for anthropogenic discharge such as wastewater, storm water runoff, or sewage treatment, for land reclamation after mining, or other ecological disturbances such as required mitigation for natural areas lost due to development. Natural wetlands act as a bio filter, removing sediments and pollutants such as heavy metals from the water, and constructed wetlands can be designed to emulate these features. Constructed wetland is an effective, efficient, simple to use, inexpensive and environmental friendly treatment method to treat the textile dyeing effluent. Studies have been carried out to check the possibility of wastewater treatment using constructed wetlands. Wetland systems can significantly reduce biochemical oxygen demand (BOD), suspended solids (SS), and nitrogen as well as metals, trace organics and pathogens [3]. The basic treatment mechanisms include sedimentation, chemical precipitation and adsorption and microbial interactions with BOD, SS and nitrogen as well as some uptake by the vegetation [8]. The main aims of this study are to establish a pilot scale plant of an integrated constructed wetland system with Free Water Surface (FWS) and Subsurface Flow (SF) that could occur both under aerobic and anaerobic conditions and to check the suitability of different species of plants to treat the effluent from the textile dyeing industry.

2. Materials and Methods

A. *Types of Wetlands*

1) Subsurface flow(SF) system

A sub surface flow system typically consists of a trench or a bed underlain by impermeable material to prevent seepage and containing a medium that supports the growth of emergent vegetation. The media used have included rock or crushed stone (10-15 cm diameter), gravel and different soils either alone or in various combinations [4]. The wastewater flows literally through the medium and is purified during the contact with the surfaces of the medium and the root zone of the vegetation. This subsurface zone is continuously saturated and therefore, is generally anaerobic. However, the plants can transfer an excess of oxygen to the root system, so there are aerobic microsites adjacent to the roots and rhizomes. Start up problems in establishing the desired aquatic plant species can be a problem with FWS and SF wetlands alike. [5,8].

2) Free water surface(FWS) system

These systems typically consist of basins or channels, with a natural or constructed subsurface barrier of clay or impervious geotechnical material to prevent seepage, soil or another suitable medium to support the emergent vegetation, and water at a relatively shallow depth flowing over the soil surface as shown in the figure 1. The shallow water depth, low flow velocity and presence of the plant stalks and litter regulate water flow and especially in long, narrow channels, ensure plug flow conditions to minimize short-circuiting [8].

B. *Experimental Setup*

A pilot scale unit consisting three separate integrated constructed wetland blocks were built at University of Moratuwa premises. Each block has two stages, subsurface flow (SF) and free water surface flow (FWS), as shown in figure 1. The SF and FWS sub systems have 15.04 l and 9 l respectively. One of those blocks is used as the control experiment block without plants. The subsurface flow consists of Typha latifolia (cattails) in both experimental blocks with plants. The free water surface of each of the block consists of Lemnaceae (Duckweed) and Hydrilla verticillata (Hydrilla) respectively.

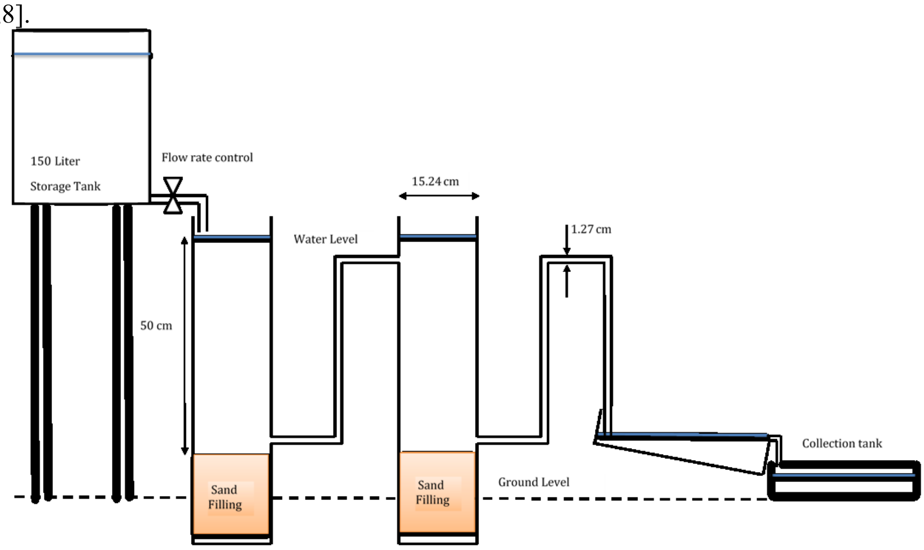

Figure 1: Schematic diagram of a block in the pilot plant

Figure 2: Pilot plant constructed at the university

Subsurface flow units were made with PVC pipes. Free water surface units were made using tanks made of glass with a polythene cover to minimize the environmental disturbances. Wastewater for the experiment was stored in a 150 litres barrel kept at an elevation of 1.5 m. Therefore, the water flow-rate through the blocks could be maintained without a mechanical pump. The Hydraulic head generated by the elevated storage barrel and the slope maintained at the free water surface units were sufficient to sustain the flow rate required for the retention time. The experimental setup constructed at the university is shown in the figure 2. The setup was made inside a shade in order to minimize the disturbances from the wind and rain.

Both synthetic wastewater and the effluent from the industry were used for the testing process. The characteristics of each type are given in table 1. Synthetic wastewater was prepared from the dyes and chemicals used in the textile dyeing process in the industry. The constituents of the synthetic wastewater are listed in Table 2.

Table 1 Characteristics of synthetic and textile wastewater

Description		**Phase 1**	**Phase 2**
Source of Waste Water		Synthetic waste water	Textile Industry
Characteristics of waste water			
pH		6.79	6.3
Chemical Oxygen Demand (mg/l)		364.5	264.5
Dissolved Oxygen (ml)		3.8	3.3
Suspended Solids (ppm)		6	4
Colour	Red	0.337	0.176
	Yellow	0.144	0.064
	Blue	0.289	0.024
Flow rate		6.5 litres/day	8 litres/day
Retention time		4 days	3 days

Table 2 Composition of synthetic wastewater

Type of Dye	**ppm**
Brilliant Violet	1.2
Luminous Red G	2
Orange S-G 200%	2.2
Yellow S-6G	6.4
Yellow 4G	4.4
Total	**16.2**
Name of the Chemical	**ppm**
Sodium hydrosulfite	7.6
Non ionic alcohol	12.6
Sulphates	8
Organic amines	4.4
Formic Acid 85%	9.2
Total	**41.8**

Phase 1

The table below summarizes the different stages of the process with remarks during phase 1.

Table 3 Process Conditions of the pilot plant in the phase 1

Run	**Date**	**Remarks**
1	15/11/2014 -18/11/2014	This was the start-up period for the setup with the wastewater from the company.
2	19/11/2014 -22/11/2014	A proper shade for the plant was not there and as a result of that rain water with mud has mixed with the effluent.
3	23/11/2014 -26/11/2014	A shade for the plant was made and all the free water surface units too were covered with polythene to make

		sure that no water will be added.
4	27/11/2014 -30/11/2014	There was a leak in the first unit and therefore water from the subsurface flow 1 did not flow into the subsurface flow 2. Therefore the unit was removed and re installed.
5	01/12/2014 -04/12/2014	Smooth run of the plant was observed
6	05/12/2014 -08/12/2014	Smooth run of the plant was observed

Phase 2

The table below summarizes the different stages of the process with remarks during phase 2.

Table 4 Process Conditions of the pilot plant in the phase 2

Run	Date	Remarks
1	09/12/2014 -11/12/2014	This was the start-up period for the setup with the wastewater from the industry.
2	12/12/2014 -14/12/2014	Colour accumulation in the root system of Duckweed was observed.
3	15/12/2014 -17/12/2014	Minus values were obtained in the readings, which imply that the concentration of the colour in the samples are lower than its presence in the distilled water.
4	18/12/2014 -20/12/2014	Smooth run of the plant
5	21/12/2014 -23/12/2014	Smooth run of the plant

C. Analytical Methods

The intensity of the colour of a water sample is characterized by its light absorption at the wavelength of maximum absorption and quantified by measuring the absorption coefficient with a filter photometer or spectrometer. Characterization of the intensity of colour of a water sample by measuring the absorption of light is the main principle in determination of true colour using optical instruments. Different colours cause maximum absorption at different wavelengths of the incident radiation. According to the standards of the Central Environmental Authority, the different wavelengths mentioned in the Table 5 were checked which have been specified for textile wastewater using DR 5000 spectrophotometer.

Table 5 Wavelengths used in the colourimeter

Wave Length	Colour
436 nm	Blue
525 nm	Yellow
620 nm	Red

D. Operational Characteristics

Two types of wastewater were used in this experiment at two phases. During the phase 1, synthetic wastewater was fed at a rate of 6.5 litres per day and during second phase the industrial wastewater was fed at a rate of 8 litres per day. The resident time at each phase was 3 days and 4 days respectively. For a similar flow rate higher resident time results in higher bed capacity. Theoretically for higher resident time a higher removal rate can be expected. During the testing phase it was found that 4 day retention time was sufficient for a significant colour removal. However, it is economical to use a lower resident time due to smaller scale wetland. Therefore the resident time was reduced to 3 days at final runs and testing was done accordingly.

3. Results and Discussion

A. Experimental results

Phase 1

The results obtained during the phase 1 of the experiment are illustrated in the figure 3, as the variation colour in different runs, as described in Table 3.

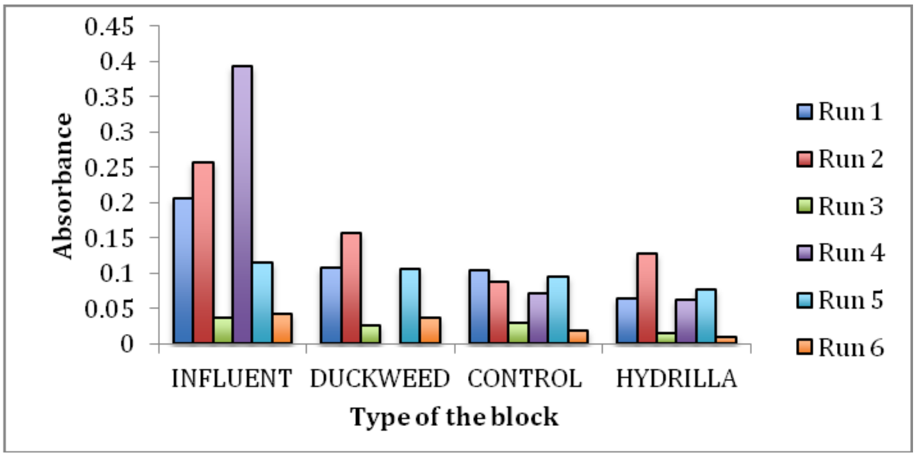

Figure 3: The variation of colour

Phase 2

The results obtained during the phase 2 of the experiment are illustrated in the graphs below, as the variation of the colour, as described in table 4.

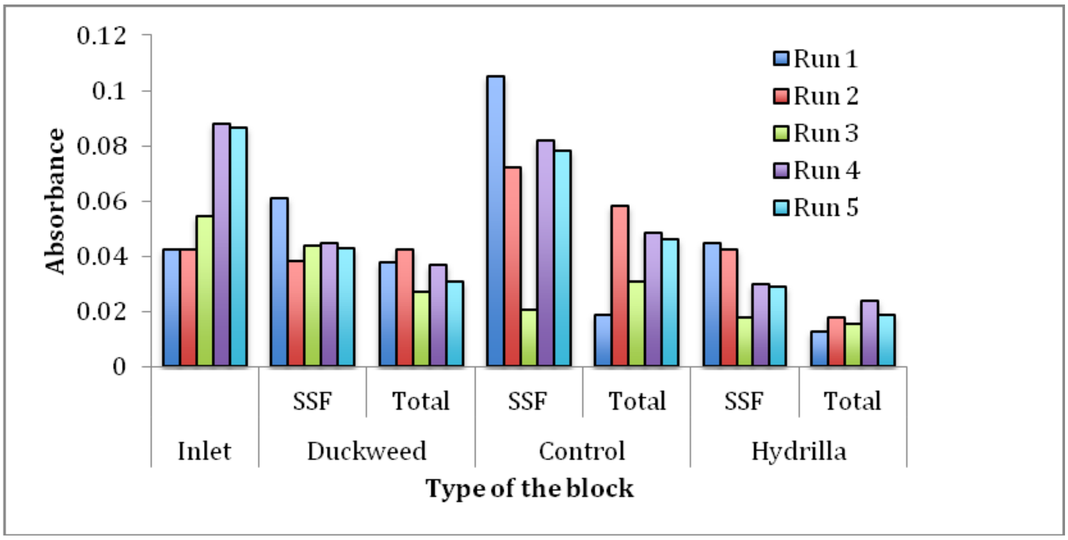

Figure 4: The variation of colour

B. Analysis of Results

The graph in the figure 5 shows the results obtained during the start-up phase of the experimental set up. According to the graph, highest rate of colour removal, 90.87% is achieved from the unit with Hydrilla in the free water surface. The control block shows a higher rate of removal than the block with Duckweed. Since this is the start-up phase of the plant, the plants require some time to adopt into the prevailing conditions.

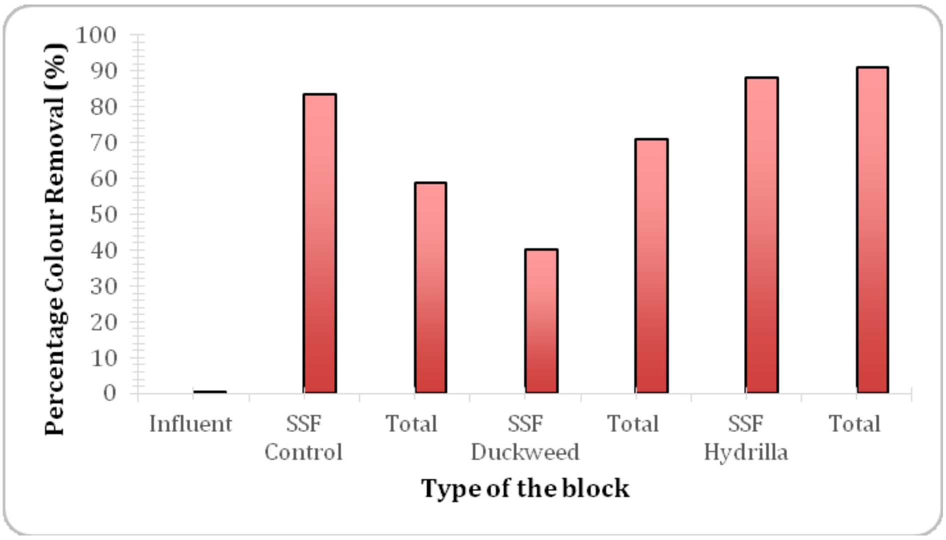

Figure 5: Percentage colour removal in the start-up phase

The graph in the figure 6 illustrates the results obtained during the process with the wastewater. This shows that the percentage colour removal in units with plants is higher compared to the unit without plants and the unit with Hydrilla in the free water surface shows the highest percentage removal of colour of 93.1% when industrial waste water was used in the process.

When synthetic wastewater was used in the process as shown in the figure 10, the highest percentage colour removal recorded was 97.31% and it was from the block where Hydrilla was used in the free water surface.

Since the rates of removal obtained in both scenarios are approximately closer to each other, it is evident that the synthetic wastewater made in the university also has similar characteristics of the wastewater.

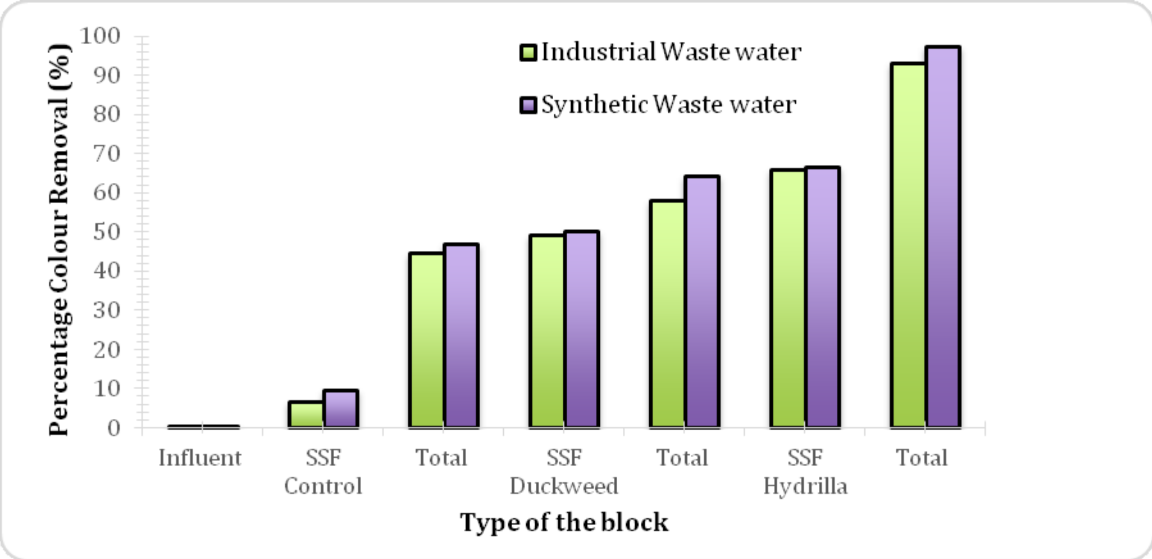

Figure 6: Percentage colour removal with industrial and synthetic wastewater

The results from figure 5 and 6 shows that the total colour removal of units with plants was higher than the control block. The total colour removal of the unit with Hydrilla in the free water surface unit was higher than the unit with the free water surface consisting of Duckweed. The rate of removal is found in the range of 90.87 to 97.31%. The results showed that the Hydrilla block could remove colour better than the Duckweed block. In addition, it is obvious that the subsurface flow block had a significant performance advantage with respect to colour. The block with plant showed much better colour removal than the control block. The reed has enzyme, plant peroxidases (POD) that are capable of degrading some textile and other important dyes [6]. The azo dyes are greatly reduced under anaerobic condition (azo bond cleavage leading to decolourization) and produce smaller molecules. On the other hand, aerobic condition cannot degrade the structure of azo dye, hence the colour removal efficiency is lower than anaerobic condition [7]

4. CONCLUSION

The results obtained indicate that the integrated constructed wetland system used in this study is capable of removing the colour in the textile dyeing effluent. The integrated constructed wetland system with plants shows higher percentage of colour removal compared to the unit without plants. The unit, which consists of Hydrilla in the free water surface, shows the highest removal efficiency compared to the unit with duckweed in the free water surface. Cattails increased the colour removal in the sub surface flow units.

5. REFERENCES

[1] F. V. Zee, I. Bisschops, V. Blanchard, R. Bouwman, G. Lettinga, J. Field, *"Water Research"*, Vol.37 (2003), p. 3098-3109.

[2] S. A. Ong, K. Uchiyama, D. Inadama, K. Yamagiwa, *"Journal of Hazardous Materials"* Vol.165 (2009), p. 696-703.

[3] M. Alkan, S. Celikcapa, Ö. Demirbas, M. Dogan, *"Dyes and Pigments"*, Vol.65, pp. 251-259, 2005.

[4] R. C. Reed, E. J. Middlebrooks, and R. W. Crites, *"Natural Systems for Waste Management and Treatment"*, McGraw-Hill, NewYork, 1988.

[5] R. K. Bastian, P. E. Shanaghan and B. P. Thompson, *"Use of wetlands for municipal wastewater treatment and disposal – Regulatory issues and EPA policies",* In Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural (ed. D.A. Hammer), Lewis Publishers, Chelsea, Michigan, 1989.

[6] C. C. Carias, J. M. Novais, S. M. Dias, "Bioresource Technology", Vol.99, p. 243-251, 2008.

[7] A. Ojstršek, D. Fa and L. Adrian *"Journal of Environmental Engineering"*.Vol.127,pp. 844-849, 2001

[8] *"U. S. E. P. A . Design Manual – Constructed Wetlands and Aquatic Plant systems for Municipal Wastewater Treatment",* EPA/625/1-88/022, United States Environmental Protection Agency, Cinicinnati, Ohio, 1988

[9] A. Bottino, G. Capannelli, G. Tocchi, M. Marcucci and G. Ciardelli, *"Membranes processes for textile wastewater treatment aimed at its re-use"*. Prec. 8th World Filtration Congress, Symposium and Exhibition Brighton, UK, pp. 521-524, 2000

[10] T. O. Okurut, *"A Pilot Study on Municipal Wastewater Treatment Using a Constructed Wetland in Uganda"*. PhD dissertation, UNESCO-IHE, Institute for Water Education, Delft, The Netherlands, 2000.

[11] J. Vymazal, *"Constructed Wetlands for Wastewater Treatment: Five Decades of Experience"*†. Environmental Science & Technology 45(1) 61-69, 2010b