Constructed wetland treatment of textile industry wastewater using aquatic macrophytes

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ABSTRACT

Textile industry processes are among the most environmentally unfriendly industrial processes, because they produce colour effluent that is heavily polluted the environment. Therefore, effluent from textile industry has to be treated before being discharged into the environment. In this study, experiments were performed to remove the pH, EC, chloride, sulphate, phenols, BOD and COD from the textile industrial effluent in constructed wetlands by using aquatic macrophytes Eichhornia crassipes. The experiments were conducted by different process parameters like nutrient dosage, dilution ratio, pH and contact time using Eichhornia crassipes to reduce the various parameters in a textile industry effluent. From the experiments it was found that the maximum percentage reduction of various parameters in a textile industry wastewater by Eichhornia crassipes were obtained at an optimum nutrient dosage of 60 g, dilution ratio of 10, pH of 8 and contact time of 6 days. Similarly, the validation experiments results showed that the maximum removal percentage of various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent is about 87.2, 90.2, 82.6, 86.8, 78.5, 91.3, and 92.8 % respectively. Finally this study was concluded that Eichhornia crassipes might be used as adsorbents for removing various parameters in a textile industry effluent.

Keywords: Textile Industry Wastewater, Process Parameters, Aquatic Macrophytes

1. Introduction

The textile industrial sector is one of the most important and largest industrial sectors in India. Among various industries, textile industry ranks first in usage of dyes for adding colours to the fibers such as cotton; animal fibers such as wool and silk; and a wide range of synthetic materials such as nylon, polyester, and acrylics (Sachin et al., 2010). Textile industries consume a large volume of water and chemicals for making various textile goods and as a result, large volume of effluent discharged on land with or without treatments. Many approaches have been taken to reduce water consumption by recycling the effluent comes from the textile industries. The raw materials particularly dyes used in the textile industry determine the volume of water required for production as well as wastewater generated (Irina-Isabella Savin and Romen Butnaru, 2008). The wastewater generated from the various processing units are desizing, scouring, bleaching, mercerizing, dyeing, printing, and packing required huge amount of organic chemicals of a complex structure (Venceslau et al., 1994; Lin and Peng, 1994, 1996; Bisschops and Spanjers, 2003). The main parameters identified in
the textile industry are pH, electrical conductivity (EC), chloride, sulphate, phenols, total dissolved solids (TDS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and other solution substances (Venceslau et al., 1994; Sofia et al., 2000). Therefore, wastewaters from the textile industry have to be treated before being discharged to the environment (Sawyer and McCarty, 1978; Vera et al., 2005).

Various methods including aerobic and anaerobic microbial degradation, coagulation (Vera et al., 2005), chemical oxidation, precipitation, filtration, membrane separation, electrochemical treatment (Lin and Peng, 1994), filtration, flotation, hydrogen peroxide catalysis, and reverse osmosis (Cooper, 1993), ozonation (Lin and Lin, 1992) and biological techniques can be employed to remove various pollutant forms the textile industry wastewater (Hoda, 2010). Activated carbon is the most widely used adsorbent due to its excellent adsorption capability in removing various pollutants in the water and wastewater but its use is often limited due to high cost. However, the costs of the activated carbon prepared from biomaterials are negligible when compared to the cost of commercial activated carbon. Some of the activated carbons used to treat the industrial wastewater in the recent past are corncob (Robinson, et al., 2002), wheat straw (Robinson, et al., 2002) groundnut husk, rice husk (Malik, 2003), barley husks (Rabinson, et al., 2002) tea leaves carbon, sawdust (Aharoni and Ungarish, 1977; Nigam and Rama, 2002; Malik, 2003), modified rice hull (Ong, et al., 2007) eucalyptus bark (Aravind and Prem, 2003), agricultural wastes, sugarcane bagasse ash (Mane et al., 2007; Sachin et al., 2010), and spent activated carbon (Weng et al., 2008). Furthermore, some of the biomaterials like neem leaf, orange peels, peanut hulls and coconut coir pith powders (Sivakumar and Shankar, 2012a, b) are used directly to reduce the contaminant concentration in the industrial effluent.

In recent years, considerable attention has been focused on absorption process using aquatic plants because, it has more advances than over conventional treatment methods include: low cost; high efficiency; minimization of chemical and biological sludge. This can be achieved by using constructed wetland. Constructed wetlands are artificial wastewater treatment systems consisting of shallow ponds or channels which have been planted with aquatic plants and which rely upon natural microbial, biological, physical and chemical process to treat wastewater. The treatment systems of constructed wetlands are based on ecological systems found in natural wetlands. For the design and construction of treatment wetlands and the processes by which constructed wetlands can remove pollutants, it is important to have a basic understanding of how natural wetlands work. Thus, this study was conducted to remove the pH, EC, chloride, sulfate, phenols, BOD and COD from the textile industrial effluent in constructing wetlands by using aquatic macrophytes Eichhornia crassipes.

2. Materials and methods

2.1 Collection of Eichhornia crassipes

The aquatic macrophytes Eichhornia crassipes were collected from the Porur Lake, Chennai, which had no connection with any textile effluent discharge points. The collected aquatic plants were washed with distilled water and weighed. Further, the aquatic macrophytes were initially subject to stabilization in small plastic tanks containing well water and the same were preserved for 15 days period. In addition, these plastic tanks were filled with gravel and wetland soil (collected from the Porur Lake) up to five inches in height and maintained at normal temperature.
2.2 Collection of textile industry effluent

For the present study, textile industry effluent samples were collected from the final clarifier of textile industrial effluent treatment plant of Chennai city, Tamil Nadu, India with the help of airtight sterilized bottles. Then, took the effluent samples to the Environmental Laboratory and then they were stored in the refrigerator at a temperature of 278 K for analyzing electrical conductivity (EC), total dissolved solids (TDS), chloride, sulphate, phenols, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in later stages. The concentration of raw effluent from textile industry effluent for various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD is given in Table 1.

Table 1: The concentration of raw effluent from tannery industry

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Parameters</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electrical Conductivity, µS/cm</td>
<td>4856</td>
</tr>
<tr>
<td>2</td>
<td>Total Dissolved Solids (TDS), mg/L</td>
<td>3108</td>
</tr>
<tr>
<td>3</td>
<td>Chloride, mg/L</td>
<td>942</td>
</tr>
<tr>
<td>4</td>
<td>Sulphate, mg/L</td>
<td>758</td>
</tr>
<tr>
<td>5</td>
<td>Phenols, mg/L</td>
<td>155</td>
</tr>
<tr>
<td>6</td>
<td>Biochemical Oxygen Demand (BOD), mg/L</td>
<td>2895</td>
</tr>
<tr>
<td>7</td>
<td>Chemical Oxygen Demand (COD), mg/L</td>
<td>3458</td>
</tr>
</tbody>
</table>

In order to reduce the various parameters in a textile industry effluent, wetlands was constructed (plastic tanks) by using aquatic macrophytes *Eichhornia crassipes* and conducted the adsorption study with various nutrient dosages, dilution ratio and contact time.

2.3 Adsorption experiments

For the experiments, the *Eichhornia crassipes*, which maintained in the plastic tanks were collected, cleaned and introduced in the experimental tanks (constructed wetland). The experimental tanks also a plastic tank as similar to the plastic tank for preserving the *Eichhornia crassipes*. Approximately, 100 g of *Eichhornia crassipes* were used in each experimental tank for this study. These experimental tanks were filled with textile industry effluent of 1000 ml. Triplicate of each experimental setup was maintained. In order to reduce the EC, chloride, sulphate, phenols, BOD and COD in a textile industry effluent, the experimental setup (constructed wetland) were examined for a period of 7 days by 1 day intervals by using aquatic macrophytes *Eichhornia crassipes* and conducted the adsorption study with various nutrient dosages (10, 20, 30, 40, 50, 60 and 70 g), dilution ratio (2, 4, 6, 8, 10, 12 and 14) and pH (4, 5, 6, 7, 8, 9 and 10). The nutrient used in this study was activated sludge which was collected from the municipal wastewater treatment plant, Chennai. The dilution ratio was used such that 1 part of effluent with various numbers of part of well water, thus, the ratio of 2, 4, 6, 8, 10, 12 and 14 represents these parts of well water mixed with raw effluent. The pH was adjusted by using 0.1 M of NaOH and 0.1 M of HCl. The concentrations of the various parameters in a textile industrial effluent before and after treatment with *Eichhornia crassipes* were determined as per the standard procedure stipulated by APPA, AWWA and WEF, 1999. The percent removals of various parameters by *Eichhornia crassipes* were calculated by using the following formula:

\[
\text{Percentage Removal} = \left(\frac{c_i - c_f}{c_i}\right) \times 100
\]
in which \( C_1 \) is the concentration of the parameter before treatment with *Eichhornia crassipes* and \( C_2 \) is the concentration of the parameter after treatment with *Eichhornia crassipes*.

### 3. Results and discussions

Selected the different process parameters like nutrient dosage, dilution ratio and contact time for conducting the constructed wetland adsorption study using *Eichhornia crassipes* to reduce the various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent.

#### 3.1 Effect of nutrient dosage

Experimental investigations were conducted by changing the nutrient dosage from 10 to 70 g with an increment of 10 g using *Eichhornia crassipes* and for the different contact time from 1 day to 7 days with an increment of 1 day. Figure 1 indicates the percentage reduction of various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent using *Eichhornia crassipes* against nutrient dosage (Since, day 6 is the optimum contact time found from the study, the results obtained on the day 6 was presented and the results obtained from the day 1, 2, 3, 4, 5, and 7 were not presented in this study) with a contact time of 6 days, dilution ratio of 6 and pH of 7.

![Figure 1: The percentage reduction of various parameters in a textile industry effluent using eichhornia crassipes against nutrient dosage](image)

The results revealed that the percentage removal of the selected various parameters is low by *Eichhornia crassipes* at the beginning and then increases with nutrient dosage. This is because, the active adsorption sites in the supplied nutrient could not be effectively utilized by the various parameters and thereafter adsorbent sites of nutrient could be effectively utilized. Up to nutrient dosage 60 g, the adsorption of various parameters in a textile industry effluent increased by *Eichhornia crassipes* steadily and for the nutrient dosage of 70 g, the percentage removal results showed the resembles of the results obtained nutrient dosage 60 g. Hence, the optimum nutrient dosage found in this study for the maximum removal of various parameters in a textile industry effluent by *Eichhornia crassipes* is 60 g.
The adsorption of various parameters in a textile industry effluent on day 7 and for the nutrient dosage of 70 g, the removal percentage for various parameters was not significant even the contact time and nutrient dosages were higher, it is more likely that an even sufficient contact time available, a significant portion of the available active sites remains undiscovered, leading to lower specific uptake for the nutrient dosage of 70 g and for the contact time of 7 days. Thus, the maximum adsorption removal percentage for various parameters in a textile industry effluent by *Eichhornia crassipes* against nutrient dosage is 86.29, 88.54, 80.78, 84.05, 76.36, 90.42, and 91.40% respectively for the parameters EC, TDS, chloride, sulphate, phenols, BOD and COD (Figure 1).

### 3.2 Effect of dilution ratio

Experimental investigations were conducted by changing the dilution ratio from 2 to 14 (effluent : well water 2) with an increment of 2 using *Eichhornia crassipes* and for the different contact time from 1 day to 7 days with an increment of 1 day. Figure 2 indicates the percentage reduction of various parameters like EC, TDS, chloride, sulphate, phenols, BOD, and COD in a textile industry effluent using *Eichhornia crassipes* against dilution ratio. (Since, day 6 is the optimum contact time found from the study, the results obtained on the day 6 was presented and the results obtained from the day 1, 2, 3, 4, 5, and 7 were not presented in this study) with a contact time of 6 days, the nutrient dosage of 60 g and pH of 7.

![Figure 2: The percentage reduction of various parameters in a textile industry effluent using eichhornia crassipes against dilution ratio](image)

The results revealed that the percentage removal of the selected various parameters is low at the beginning and then increases with dilution ratio. This is because, diluted concentration of all parameters in a textile industry effluent were adsorbed easily by the *Eichhornia crassipes* than a highly concentrated aqueous solution. In other words, the active sites in the *Eichhornia crassipes* could not be effectively utilized by the various parameters at the beginning and thereafter adsorbent sites of *Eichhornia crassipes* could be effectively utilized in later stages. Up to dilution ratio of 10, the adsorption of various parameters in a textile industry effluent by *Eichhornia crassipes* increased steadily and in the dilution ratio 12 and 14, the percentage removal results showed the resembles of the results obtained for the dilution ratio 10. Hence, the optimum dilution ratio found in this study for the maximum removal of various parameters in a textile industry effluent is 10.
The adsorption of various parameters in a textile industry effluent on day 7 and for the dilution ratio 12 and 14, the removal percentage for various parameters was not significant even the contact time and dilution ratio were higher, it is more likely that an even sufficient contact time available, a significant portion of the available active sites remains undiscovered, leading to lower specific uptake for the dilution ratio 12 and 14 and for the contact time of 7 days. Thus, the maximum adsorption removal percentage for various parameters in a textile industry effluent by Eichhornia crassipes against dilution ratio is 72.8, 75.05, 66.08, 70.25, 62.60, 76.10 and 78.75 % respectively for the parameters EC, TDS, chloride, sulphate, phenols, BOD and COD (Figure 2).

3.3 Effect of pH

Experimental investigations were conducted by changing the pH from 4 to 10 with an increment of 1 using Eichhornia crassipes and for the different contact time from 1 to 7 days with an increment of 1 day. Figure 3 indicates the percentage reduction of various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent using Eichhornia crassipes against pH (Since, day 6 is the optimum contact time found from the study, the results obtained on the day 6 was presented and the results obtained from the day 1, 2, 3, 4, 5, and 7 were not presented in this study) with a contact time of 6 days, the nutrient dosage of 60 g and dilution ratio of 10.

The results revealed that the percentage removal of the selected various parameters is low at the beginning and then high with pH increases. This is because, with a slight alkaline to alkaline condition, the active sites in the Eichhornia crassipes could be effectively utilized by the various parameters at the alkaline condition than in acidic condition. Up to a pH of 8, the adsorption of various parameters in a textile industry effluent by Eichhornia crassipes increased steadily and for the pH 9 and 10, the percentage removal results showed the resembles of the results obtained for the pH 8. Hence, the optimum pH found in this study for the maximum removal of various parameters in a textile industry effluent is 8.
time and pH were higher, it is more likely that an even sufficient contact time available, a significant portion of the available active sites remains undiscovered, leading to lower specific uptake for the pH of 9 and 10 and for the contact time of 7 days. Thus, the maximum adsorption removal percentage for various parameters in a textile industry effluent by *Eichhornia crassipes* against pH is 82.34, 86.73, 77.35, 79.97, 73.02, 87.09, and 89.4 % respectively for the parameters EC, TDS, chloride, sulphate, phenols, BOD and COD (Figure 3).

### 3.4 Verification experiment

In order to validate the above experiments in reducing the various parameters in a textile industry effluent, a separate experiment has been performed with an optimum nutrient dosage (60 g), dilution ratio (10), pH (8) and contact time (6 days). The maximum removal percentage for various parameters in a textile industry effluent by *Eichhornia crassipes* is shown in Figure 4. The results (Figure 4) showed that the maximum removal percentage for various parameters in a textile industry effluent by *Eichhornia crassipes* is about 87.2, 90.2, 82.6, 86.8, 78.5, 91.3, and 92.8 % respectively the parameters EC, TDS, chloride, sulphate, phenols, BOD and COD.

From Figures 1, 2 and 3, it was found that up to contact time of 6 days, the adsorption of various parameters in a textile industry effluent by *Eichhornia crassipes* increased steadily and on the day 7, the percentage removal results showed the resembles of the results obtained on day 6. Hence, the optimum contact time found in this study for the maximum removal of various parameters in a textile industry effluent by *Eichhornia crassipes* is 6 days.

![Figure 4: The percentage reduction of various parameters in a textile industry effluent using *Eichhornia Crassipes* against optimum nutrient dosage (60 g), dilution ratio (10), pH (8) and contact time (6 days)](image)

Based on the results, it may be concluded that *Eichhornia crassipes* may be used as adsorbents for removing the various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent.
4. Conclusion

In the present study, the experiments were conducted to find out the suitability of *Eichhornia crassipes* in removing the various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent. The ability of *Eichhornia crassipes* for removing various parameters in a textile industry wastewater by various nutrient dosages, dilution ratio, pH and contact time were monitored. The maximum percentage reduction of various parameters in a textile industry wastewater by *Eichhornia crassipes* were obtained at an optimum nutrient dosage of 60 g, dilution ratio of 10, pH of 8 and contact time of 6 days. From the validation experiments, it was found that the maximum removal percentage of various parameters like EC, TDS, chloride, sulphate, phenols, BOD and COD in a textile industry effluent is about 87.2, 90.2, 82.6, 86.8, 78.5, 91.3, and 92.8 % respectively. The validation results were higher than the results obtained by different process parameters values. From the results of various process parameters, *Eichhornia crassipes* might be used as adsorbents for removing various parameters in a textile industry effluent.

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5. References


