2011 International Conference on Environmental and Computer Science
IPCBEE vol.19(2011) © (2011) IACSIT Press, Singapore

Electrochemical Treatment of Textile Dye Wastewater Using Stainless Steel Electrode

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Abstract. Electrochemical oxidation for a textile dye wastewater collected from a textile processing industry was investigated in this study using Stainless Steel (SS) as an anode. A number of batch experiments were run in a laboratory-scale that was analyzed at every 30 min regular intervals, for a total period of 180 min. The results are reported in terms of percentage removal of Chemical Oxygen Demand (COD), Color and variations in BOD_5/COD ratio for different current densities of 12 A/m^2, 24 A/m^2 and 48 A/m^2. For the different current densities, COD was reduced by 52%, 63% and 71% respectively; Color was reduced by 41%, 55**%,** and **77%** respectively. Biodegradability improved because of the increase in BOD_5/COD ratio from 0.1 to 0.58. Also, increased current density improved the anode oxidation and removal rate of pollutants. It can be concluded from the results that SS as an anode found to be effective in treating this electrolyte and could be effectively used for pretreatment.

Keywords: Electrochemical Oxidation, COD, Color, Stainless Steel, Textile dye wastewater.

1. Introduction

In general, the wastewater generated from textile industries is found to contain high degree of pollutants with high total dissolved solids and suspended solids. The wastewater is highly colored and viscous due to dyestuff and suspended solids respectively. Sodium is the only major cation due to high consumption of sodium salts in processing units, chloride is the major anion found in the wastewater, the concentrations of bicarbonate, sulphate and nitrate are also high. Heavy metals like chromium, iron, lead, zinc, copper, manganese are also present. BOD_5 and COD parameters are also high and BOD_5/COD ratio is anywhere between 0.15-0.3, which indicates the recalcitrant nature of organics present in the wastewater (Hussain, et.al., 2004).

Recently there has been growing interest towards electrochemical techniques for the treatment of wastewater containing organic pollutants. Two important features of the electrochemical process are converting non-biocompatible organics into biocompatible compounds and oxidation of organics into carbon dioxide and water (Karuppan Muthukumar, et al., 2004).

2. Theories of Electrochemical Treatment

A typical electrochemical treatment process consists of electrolytic cell, which uses electrical energy to affect a chemical change. In simplest forms, an electrolytic cell consists of two electrodes i.e. anode and cathode, immersed in an electrical conducting solution (the electrolyte), and are connected together, external to the solution, via an electrical circuit which includes a current source and control device. The chemical processes occurring in such cells are oxidation and reduction, taking place at the electrode/electrolyte interface. The electrode at which reduction occurs is referred to as the cathode and conversely, the anode is the electrode at which oxidation processes occur.

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The current flow in an electrochemical cell is maintained by the flow of electrons resulting from the driving force of the electrical source. In order to allow the current to flow, there must be an electrolyte, which facilitate the flow of current by the motion of its ionic charged species. Type of electrolyte has significant effect on the process in the formation of oxidizing species during the process (Chen, 2004).

3. Methods

The electrochemical cell consists of an undivided reactor with two parallel electrodes having an inter-electrode gap of 40 mm. The electrochemical cell has a volume of 1000ml. Both anode and cathode were placed vertical and parallel to each other. The electric power required during the electrolysis was provided by a laboratory Dual DC power supply (Textronix 35D, 0-15V, 0-10A). The electrolytic cell was equipped with a magnetic stirrer in order to keep the electrolyte well mixed. The schematic diagram of the experimental setup is shown in Fig.1 which consists of a borosil glass beaker of one litre capacity as the electrolytic cell. In this study, individual effects of electrode surface area and applied current on decolorization rate and COD removal were quantified. Commercially available Stainless Steel (SS) of 5 cm * 5 cm dimension was used as anode and cathode. The electrolysis was carried out under galvanostatic conditions covering a wide range of operating conditions.

3.1. Analysis

The pH measurements were made on Elico Ion Analyser (LI 126). COD of the effluent sample was determined by closed reflux method, using COD digestion apparatus Model ET 108, Lovibond. The absorption spectra of the samples were recorded on Elico Scanning Mini Spectrophotometer (SL 177), recording the spectra over 340nm to 1000nm range. The characteristics of industrial effluents were determined according to the standard methods. All the reagents were prepared and analyzed as per standard methods for the examination of water and wastewater. To estimate the color removal, the disappearance of the absorbance peaks of the solution was monitored. Color removal ratio was calculated as follows: $Abs(\%)= [(Abs_i-Abs_f)/Abs_i] *100$ where, Abs(%) = Absorbance in percentage, Abs_i= Initial absorbance of the raw sample, Abs_f = Absorbance of the treated samples at regular intervals.

3.2. Methodology

The efficiency of the electrolytic cell was studied with different current densities (Current density i.e., the current per area of electrode). Each experiment was of batch operation with duration of 180 min. For every 30 mins samples were taken and magnitude of COD, BOD_5 and Color were measured. Before each run electrodes were rinsed with tap-water, dried at 103 ^oC cooled and weighed. At the end of each run, the electrodes were washed thoroughly with water to remove any solid residues on the surface, dried and reweighed. When too large current is used, there is a high chance of wasting electrical energy in heating up the water. More importantly, a too large current density would result in a significant decrease in current efficiency. In order for the Electro Coagulation system to operate for a long period of time without maintenance, its current density is suggested to be 20-25 A/m^2 unless there are measures taken for a periodical cleaning of the surface of electrodes (Guohua Chen, 2004). For the present study current densities of 12 A/m^2, 24 and 48 A/m^2 were selected and studied for various parameters.

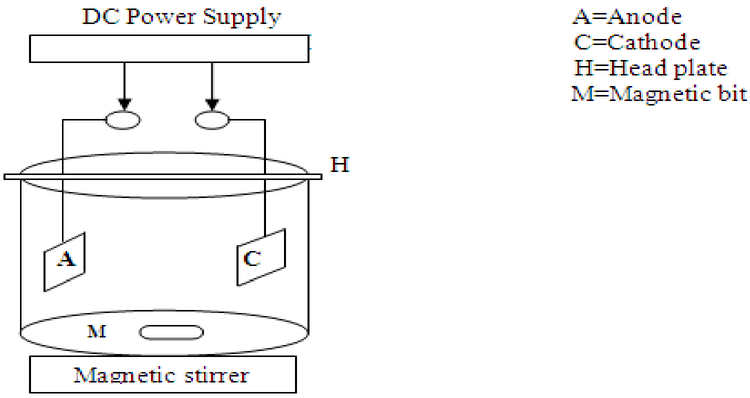

Fig.1: Schematic Diagram of an Electrochemical Cell.

4. Results and Discussions

The characteristics of the Textile Dye wastewater (TDW) are given in Table 1. It is known from the literature that initial pH does not have significant effect in the degradation of organic pollutants by indirect electrochemical oxidation. Hence in the present study, the electrochemical degradation experiments for the effluents were conducted without pH adjustments. All the experiments were conducted at fixed current densities of 12 A/m^2, 24 A/m^2 and 48 A/m^2.

Table.1: Characteristics of Raw Textile Dye wastewater

Parameter	Values
pH	9.2
Total Solids	1244
Total Dissolved Solids	541
Total Suspended Solids	28
Total Volatile Solids	660
Alkalinity	440
Chlorides	1200
BOD	307
COD	3162
BOD_5/COD	0.10

(Except pH and BOD_5/COD all the parameters in mg/l)

4.1. Chemical Oxygen Demand (COD)

The variation of COD with electrolysis time for different current densities is presented in Fig. 2. It can be ascertained from Fig. 2, COD decreases with increasing electrolysis time. The trend of COD reduction with electrolysis time remains same for all the current densities adopted in the present investigation. Also rate of COD reduction increases with increasing current density. Mohan et.al, (2001), reported COD reduction for different current densities varying from 1 to 5 A/m^2, COD reduction increased for a max current density of 5 A/m^2. When the current density is high, significant decrease in the current efficiency is expected from the production of oxygen where Current efficiency CE, the ratio of current consumed in producing a target product to that of total consumption (Guohua Chen, 2004).

4.2. Color

Color removal is of great interest because color is considered as the most important persisting polluting parameter of TDW. Fig. 3 shows the reduction of color by absorbance with spectrophotometer under various experimental conditions. The rate of color removal increases with increasing current density. This is consistent with Faraday's law according to which the hypochlorite content increases with current density. The removal of color was increased with increasing current density of max 48 A/m^2.

4.3. Biochemical Oxygen Demand (BOD_5)

It is observed that BOD_5 has increased during the course of reaction as shown in Fig. 4. The increase in BOD_5 concentration is attributed to the fact that some of the organics may have broken down into smaller fragments, which are more biodegradable than the parent compounds.

4.4. BOD_5/COD Ratio

It is observed that increase in BOD_5/COD ratio is an indicator of biodegradability with increase in electrolysis duration. The BOD_5/COD ratio for TDW is about 0.58. Fig.5 shows that during electrolysis the BOD_5/COD ratio has been increased. Thus for 12 A/m^2, 24 A/m^2 and 48 A/m^2 of current densities increase in BOD_5/COD ratio was 0.30, 0.43 and 0.58 respectively.

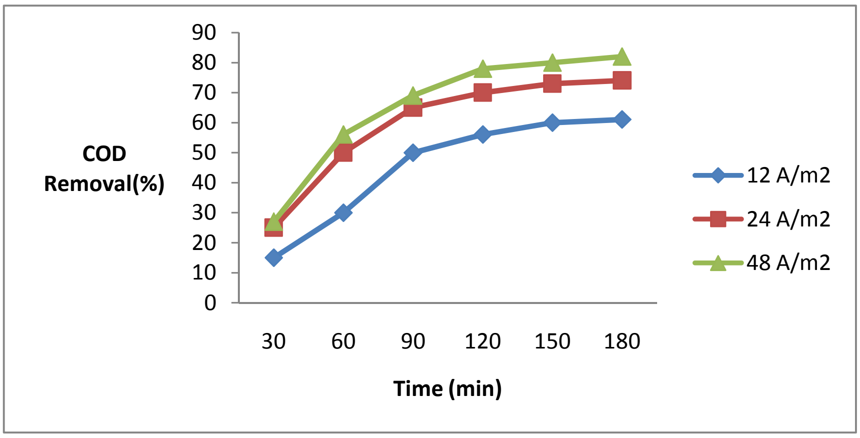

Fig.2: Percentage Removal of COD at Different Current Densities.

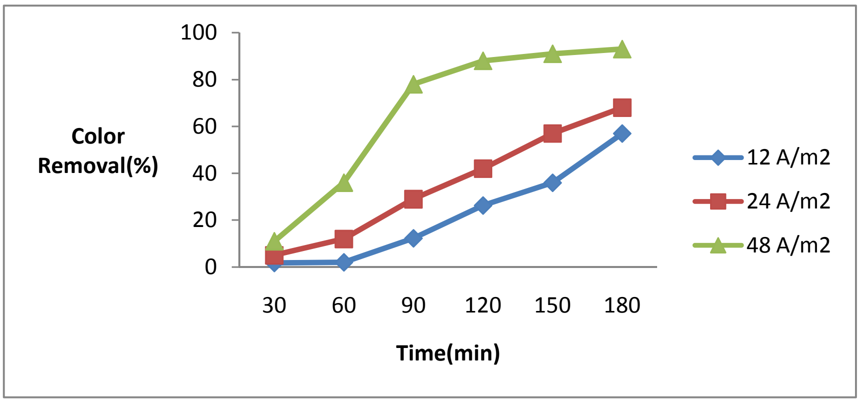

Fig.3: Percentage Removal of Color at Different Current Densities.

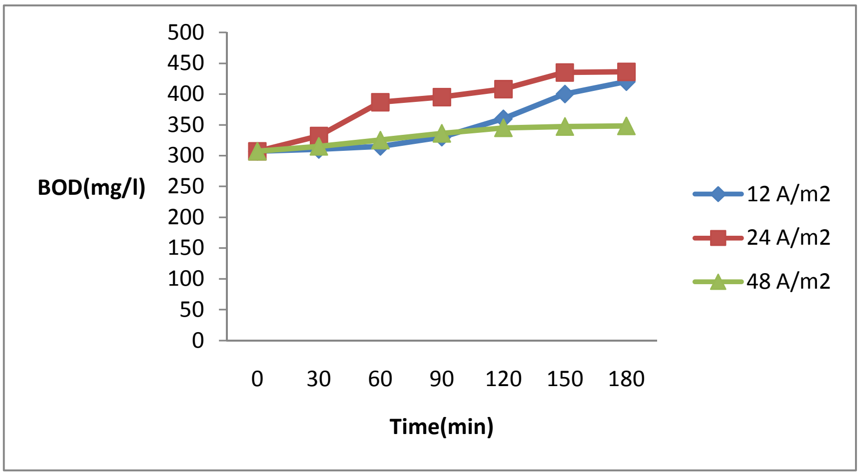

Fig.4: Variation in BOD_5 at Different Current Densities.

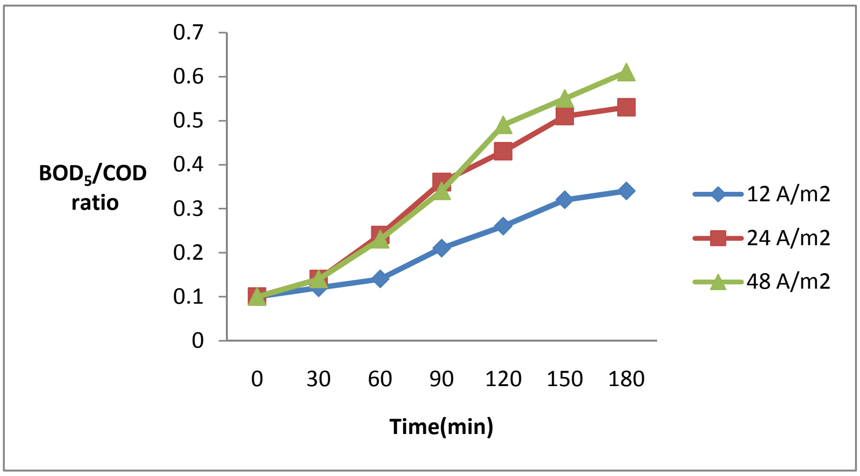

Fig.5: Variation of BOD_5 /COD Ratio at Different Current Densities.

5. Conclusions

In the present investigation, electrochemical method has been found to be effective in treating TDW. At a current density of 48 A/m^2, maximum color removal of 77%, COD reduction of 71% and increase in BOD_5/COD ratio from 0.1 to 0.58 is achieved. Also, increased current density increased the anode oxidation and removal rate of pollutants. Hence, it can be concluded that electrochemical treatment can be used as a pretreatment technology to treat this electrolyte.

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