Optimization of decolorization and COD removal from textile wastewater using Electro Fenton process with Ti/IrO_2 electrodes

N. D. D. Duc [*1,2)], ***N. T. A. Thu*** [*2)], ***P. T. Nghia*** [*2], ***N. T. Phong*** [*1)]
1) Bach Khoa University, Viet Nam
2) Ho Chi Minh City University of Food Industry, Viet Nam
****ntphong@hcmut.edu.vn***

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Introduction

The wastewater from dyes and dye manufacturing industry causes serious impact on natural water bodies and land in the surrounding area. This wastewater contains high organic loading and may have the presence of toxic or presence of bio-recalcitrant compounds, hence the application of biological treatment is not feasible (Azbar 2004). The structure of dye molecules is generally complex and stable to heat and light. Furthermore, synthetic dyes usually contain aromatic rings which are harmful and non-biodegradable.

The drawbacks of traditional physico-chemical processes are related to cost and the generation of large volume of sludge (Ahmad 2010). On the other hand, advanced oxidation processes (AOPs) offer effective and rapid alternative treatments for various persistent contaminants until their overall mineralization, base on the in situ generation of hydroxyl radicals (Marco Panizza et al. 2011).

There are various electrode materials and IrO_2 is known as a high conducting, lifelong metal oxide. To the best of our knowledge, the optimization of decolorization and COD removal from real textile wastewater using Electro Fenton (EF) process with Ti/IrO_2 electrodes has not reported previously. The aim of this study was to achieve optimal operating condition of three parameters, including the amount of Fe^{2+} used, initial COD and applied current density for the efficiency of COD and color removal from real textile wastewater.

Material and Methods

Wastewater Sampling: Wastewater was collected from the equalization tank of THANHCONG textile garment investment trading joint stock company wastewater treatment plan. The textile wastewater was pre-treated by coagulation/flocculation method with $FeCl_3$ 1% w/w in order to eliminate Total suspended solid (TSS).

Materials and Apparatus:K_2CrO_7 (Merck, Germany), $FeSO_4.7H_2O$ (Merck, Germany), and $Fe(NH_4)_2(SO_4)_2.6H_2O$ (Merck, Germany) were purchased to analyze COD. An UV–VIS spectrometer was used to measure color of the wastewater. pH was measured using a pH meter (WTW Inolab 7110, Germany).

The reactor (**Fig. 1**) was made by a 500ml glass beaker. Electrodes were connected to the current power supply (MATRIX MPS-3005S). The distance between electrodes was kept 2 cm in all experiments. The air was pumped at 1 l_{air}/l_{sample}/min near the cathode and Fe^{2+} was added at different concentrations for each experiment. Magnetic stirring was used to avoid concentration gradients. Before and after each experiment, the electrodes were washed properly using HCl acid solution followed by distilled water. Electro Fenton was then performed for 30 min under differential dosages of Fe^{2+}, and H_2SO_4 which were adjusted for each set experiment. Next, the pH of solution was adjusted to 7 using 1N NaOH and water sample was taken to centrifuge. The supernatant was then taken for COD and color analyses.

Response Surface Analysis: Experimental designs were made by using Modde 5.0 (Umetrics, Umea, Sweden). Based on Box -Behnken Design, 15 experiments were designed for 3 factors at three levels, included current density (x_1; 20, 30, 40 mA/cm^2), initial COD (x_2; 320, 480, 640 mg/l), and Fe^{2+} concentration (x_3; 6, 10, 14 mMol).

Results and Conclusions

Second-order Polynomial Equation: An empirical relationship expressed by a second-order polynomial equation was fitted between the experimental and input variables, as shown in following equations:

$Y_1 = 93.31 - 3.1225x_1 - 1.66667x_2 - 8.60249x_1x_1 - 6.37416x_2x_2 - 6.93583x_3x_3 + 1.25x_2x_3$; $R^2 = 0.939$ $R^2_{adj} = 0.923$, p value (regression)= 0.000, p value (lack of fit) = 0.415.

$Y_2 = 98.2667 - 0.459165x_2 + 0.312092x_3 - 1.15041\ x_1x_1 - 0.922908x_2x_2 - 0.723744x_3x_3 + 0.276667x_1x_2 - 0.542503x_1x_3 - 0.621668x_2x_3$; $R^2 = 0.912$, $R^2_{adj} = 0.890$, p value (regression) = 0.000, p value (lack of fit) = 0.528.

Determination and Application of Optimum Condition of Treatment: Application of Modde 5.0 provided us the minimal point which represented the optimum condition for the treatment, as can be seen from **Fig.** 2. Accordingly, the optimal condition was at J = 28.9 mA/cm^2, CODin = 449.5 mg/l, Fe^{2+} concentration of 10.7 mMol. Operating at this condition resulted in the predicted efficiency of color and COD removal of 98.3 % and 93.5 %, respectively.

Conclusions: The Electro Fenton process with Ti/IrO_2 electrodes was successfully optimized for decolorization and COD removal from real textile wastewater using Response surface methodology – Box Behnken design. The regression polynomial equations were formulated for the relations between variables (Fe^{2+} concentration, initial COD concentration , applied current density) and responses (efficiency of color and COD removal) with coefficient of determination (R^2) value of 0.939 (for Y_1) and 0.912 (for Y_2). At Fe^{2+} concentration of 28.9 mMol, initial COD of 449.5 mg/l and applied current density of 28.9 mA/cm^2, the treatment system reached its optimum operating condition, resulted in the predicted color output of 12.3 Pt-Co and COD output of 29.1 mg/l. Extended discussion about the effect of Fe^{2+} concentration, pH and voltage on color and COD removal was given based on the results from the developed model. Finally, the results from this study confirmed that Electro Fenton process is a promising solution to treat textile wastewater since the color and COD effluent from this process met well the national standard, QCVN 13:2015/BTNMT.

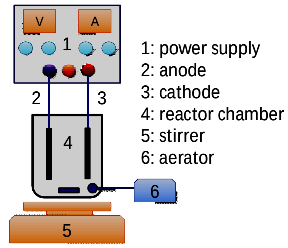
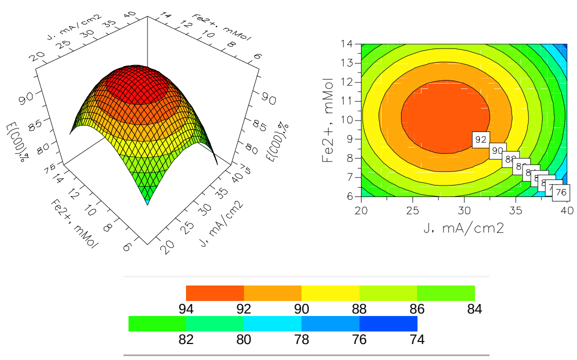
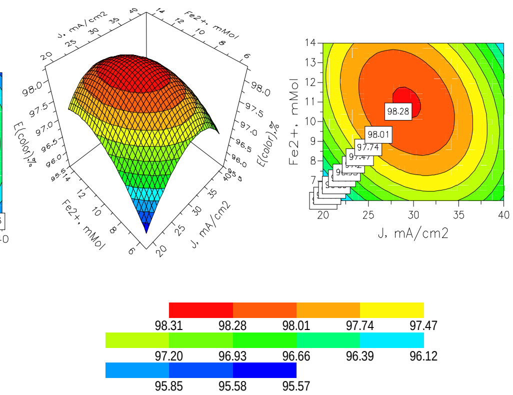


Figure 1. schema of the reactor

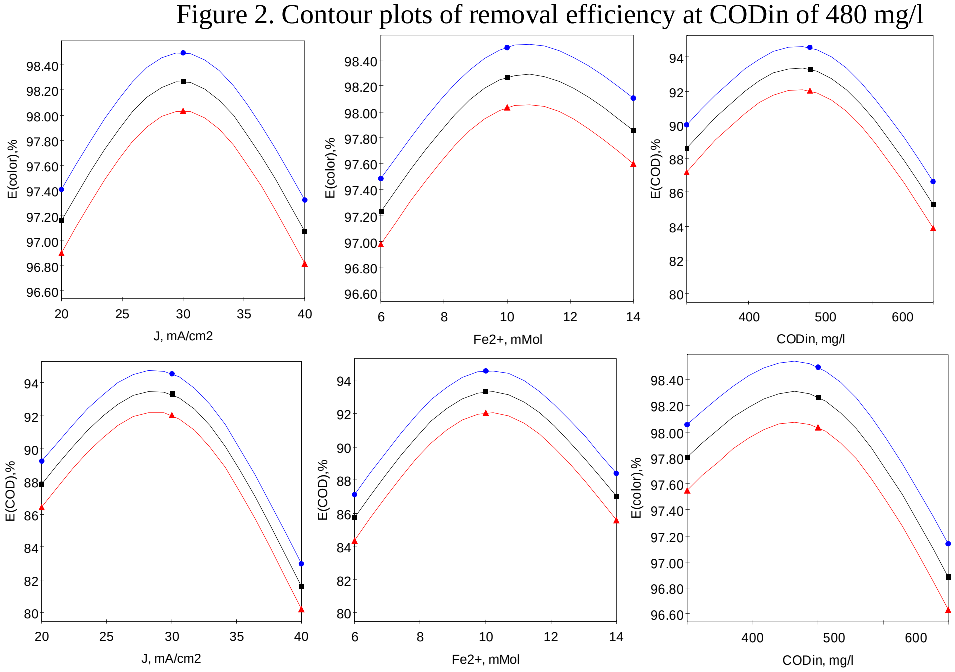


a. COD removal efficiency plots



b. Color removal efficiency plots

Figure 2. Contour plots of removal efficiency at CODin of 480 mg/l



§ Color • Upper confident interval • Lower confident interval

Figure 3. Prediction plots of variables to color removal efficiency

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