Available online at www.elixirpublishers.com (Elixir International Journal)

Chemical Engineering

Elixir Chem. Engg. 49 (2012) 9842-9844

ISSN: 2229-712X

Artificial neural network modeling for decolorization of textile dye effluent

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ARTICLE INFO

Article history:
Received: 6 June 2012;
Received in revised form: 23 July 2012;
Accepted: 2 August 2012;

Keywords
Continuous stirred tank Electrochemical reactor;
Textile effluent;
Color removal,
Artificial neural network.

ABSTRACT

The aim of the present study is to treat the textile effluent using Continuous Stirred Tank Electrochemical reactor [CSTER]. RuO_2 coated Ti and stainless steel were used as an anode and cathode respectively. The influence operating parameter such as effluent flow rate, initial effluent concentration, current density and initial pH of the effluent has been studied for the color removal of the effluent. The maximum color removal has been achieved at lower flow rate, lower initial effluent concentration and higher current density and alkaline pH. An artificial neural network (ANN) model has been developed to predict the performance of percentage color removal by electro oxidation process based on experimental data obtained in a laboratory using Continuous Stirred Tank Electrochemical reactor. A comparison between the predicted results of the designed ANN model and experimental data matches well for the 4-3-1 net work.

Introduction

Effluents from the textile industry are not only colored but also contain large amounts of color, COD, BOD and dissolved solids. Textile industry is the one producing huge amount of wastewater. Due to stringent environmental regulations, treatment is mandatory before discharge the effluent. Conventional treatment methods include activated carbon adsorption, solvent extraction, chemical and biological methods. These methods are having their own pros and cons when they applied individually [1]. Recent years advanced oxidation technique is growing much faster to treat the industrial effluents. Due to the increasing economic, social, legal and environmental pressure the best available technology to perform without producing any secondary pollution is electrochemical technology. The advantage of electrochemical treatment has environmental compatibility, versatility, energy efficiency, safety, selectivity, amenability to automation, and cost effectiveness [2].

Electrochemical methods have been successfully applied in treatment of several industrial waste waters [3-6]. Fernandes et al., [7] studied the electro oxidation of CI Acid Orange 7 using boron doped diamond electrode. Yusuf Yavuz and Savas Koparal [8] studied the electro oxidation of phenol in a parallel plate reactor using Ruthenium metal oxide electrode and Apostolos Vlyssides et al., [9] studied the degradation of methyl parathion in aqueous solution using Ti/Pt and Stainless steel as the electrodes. Kinetic modeling of electro oxidation process is very difficult to determine because of various steps involved in the electro oxidation, leading to uncertainties in the design and scale –up of chemical reactors of industrial interest. An alternative modeling technique to model the process is Artificial Neural Networks (ANN). ANN does not require any mathematical description of the phenomena involved in the process, and might therefore prove useful in simulating and up-scaling complex electro oxidation systems. The network strongly depends on the process variables involved in the process as well as set of data and the domain used for training purpose [10, 11].

In the present study decolourization of textile effluent containing Acid Red 88 dye effluent by electro oxidation method has been investigated. The effects of operating parameters such as Effluent flow rate, initial effluent concentration, current density and initial pH on color removal efficiency have been investigated. An important objective was to obtain an ANN model that could make reliable prediction of the color removal efficiency of the electro oxidation process.

Material and methods

Experimental

The commercial dye used in this investigation was purchased from Qualigens Fine Chemicals, Mumbai, India. The chemicals used in the study were of analytical grade. The chemical structure and other characteristics of this dye are shown in Table 1.Dye solution was prepared by dissolving the dye in the distilled water. The electrolyte concentration was adjusted using sodium chloride (NaCl). The electro oxidation was carried out in a Continuous Stirred Tank Electrochemical reactor. Schematic of an experimental set up is shown in Figure 1. Experiments were conducted in a Continuous Stirred Tank Electrochemical Reactor having 300 ml capacities. Oxide coated titanium metal is used as anode and stainless steel is cathode. Experiments were carried out under galvanostatic conditions using a DC-regulated power source (HIL model 3161) of 0–5A and 0–30V. Synthetically prepared Acid Red 88 dye effluent is taken in the cell and uniform mixing is achieved by using magnetic stirrer. Samples were collected periodically and analyzed. The pollutant degradations were estimated by UV/Visible spectrophotometer (Hitachi, Japan).

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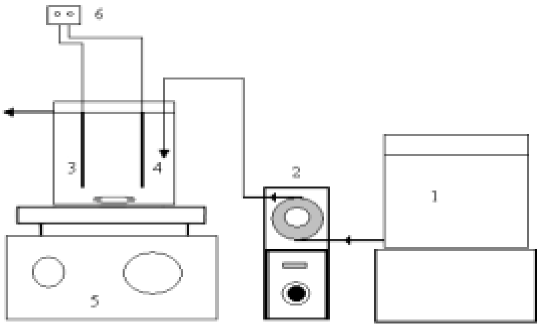
ANN software

All ANN calculations were carried out using MATLAB 7 mathematical software with ANN toolbox .A four input variable with one hidden layer and one out put layer has been selected. Single layer net work with a sigmoidal transfer function (*trainscg*) with back propagation algorithm was designed in this study.

Figure 1: Schematic representation of continuous Stirred Tank Electrochemical Reactor; 1: Over head Tank; 2: peristaltic pump 3: Anode; 4: Cathode; 5: Magnetic stirrer. 6: DC power supply.



Result and discussion

Artificial Neural Network

Artificial neural network require at least three normal types of layers—input, hidden and output. In the present work, the input variables to the feed forward neural network are as follows: Flow rate, current density, initial effluent concentration and initial solution pH. Color removal percentage is the experimental response or output variable. The sigmoidal transfer function is used as a transfer function in the hidden layer.

Figure 2: Effect of current density on color removal. Flow rate 25 l hr^{-1}; Initial effluent concentration: 50 mg l^{-1}; pH : 7

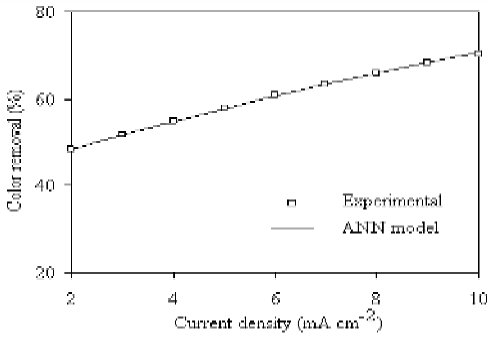
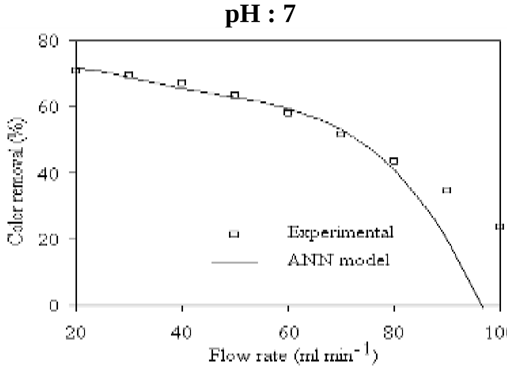


Figure 3 : Effect of flow rate on color removal. Current density 10 mA cm^{-2}; Initial effluent concentration: 50 mg l^{-1}; pH : 7



There are three steps in the ANN, training, validation and simulation. Back propagation neural network performed for training the samples with known experimental response. The training is repeated until the convergence is reached by changing the number of neurons and hidden layers. In the present study, feed-forward ANN model is designed in back-propagation training algorithm using the Neural Network Toolbox of MATLAB 7. One and four neurons are devoted to output and input layers respectively. All inputs and outputs are linearly normalized before entering in ANN, using the following equation [10]:

$$A_i = \frac{(X_i - X_{min})}{(X_{max} - X_{min})}(r_{max} - r_{min}) + r_{min} \qquad ((1)$$

where X_i is input or output of the network, Ai is the normalized value of X_i, X_{min} and X_{max} are extreme values of X_i, and r_{min} and r_{max} define the limits of the range where X_i is scaled. In this work, input and output data are normalized between –1 and 1; and 0.2 and 0.8 respectively. After modeling, results are converted to original state. In the present study, different combinations of 82 color removal data are collected. These data are split in to training and validation. Randomly 70 data are selected and it is used for the training and the remaining used for the validation. Based on this result the number hidden layer has been selected as one with thee neurons.

Figure 4 : Effect of initial effluent concentration on color removal. Flow rate 25 l hr^{-1}; current density 10 mA cm^{-2}; pH : 7

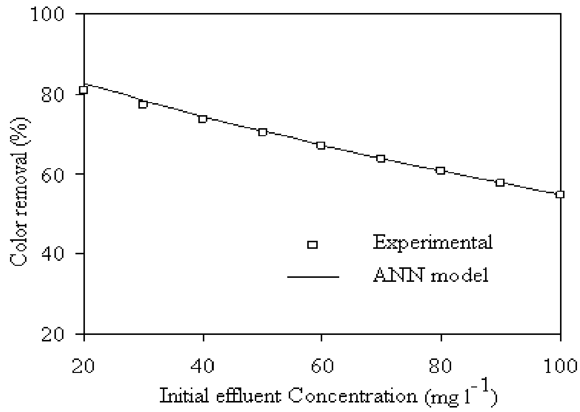
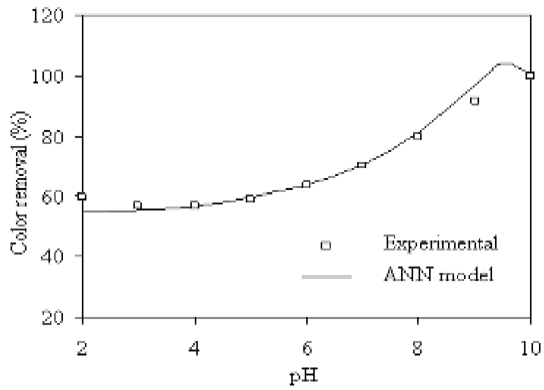


Figure 5 : Effect of pH on color removal. Flow rate: 25 l hr^{-1}; current density: 10 mA cm^{-2}; Initial effluent concentration: 50 mg l^{-1}.



Effect of current density

Experiments are carried out for five different current densities keeping other parameters constant. The color removal rate increases with current density. This may be due to the fact that the rate of generation of hypochlorite ion increased with current density, which eventually increases the pollutant degradation. The experimental and ANN simulation is shown in the Figure 2. It is observed from the figure the model perfectly match with the experimental result.

Effect of flow rate

The effect of various flow rates on color removal has been studied. The flow rate increases the rate of color removal decrease. This is due to when the flow rate increase eventually decreases in residence time. The ANN model simulation with the experimental result is depicted in the Figure 3. It is observed from the figure the ANN model satisfactory matches with experimental result.

Effect of initial effluent concentration

In order to study the rate of degradation, various initial effluent concentrations have been varied. The degradation rate is decreased with increase in effluent initial concentration. This may be explained that the ratio of OCl^- to the effluent concentration decreases with increase in effluent initial concentration. Figure 4 shows the ANN model simulation with experimental result. It can be observed from the Figure model matches well with experimental result.

Effect of pH

Experiments were conducted under acid, alkaline and neutral conditions and the observed results are compared with ANN model simulation. It can be ascertained from Figure 5 that the rate of color removal increased significantly when the electrolyte pH increased. Increase in electrolyte pH increases the OH radicals favors the hydrolysis reaction and consequently the rate of oxidation. The reaction was favorable at neutral and alkaline conditions.

Conclusion

In the present study focuses the treatment of dye house effluent using electrochemical techniques covering wide range of operating conditions in a Continuous Stirred Tank Electro Chemical Reactor. The influence of initial effluent concentration, current density, flow rate and pH on color removal has been critically examined. The color removal rate is decreased with increasing initial effluent concentration and effluent flow rate. Further the Artificial Neural network model results predicted the output results for the dye effluent color removal. It can be concluded that the network configuration (4-3-1) gives better result to predict the experimental results.

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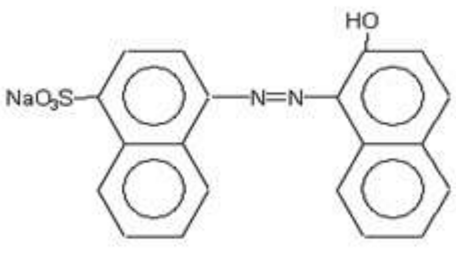
Table 1: Properties and Structure of Acid Red 88 dye

Chemical Structure	Commercial Name	Molecular weight	λ_{max} (nm)	Molecular Formula
	Acid Fast Red	400.39	503	$C_{20}H_{13}N_2NaO_4S$