



## Decolorisation of Reactive Congo Red Dye Solution by Electro Coagulation Process

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### Abstract

The decolourisation of the reactive Congo red dye from synthetic wastewater was studied using ElectroCoagulation (EC) technique.

In an effort to increase removal efficiency, the effects of operating parameters including flow, inter electrode distance, conductivity, voltage, and Hydraulic Detention Time (HDT) were investigated.

An electrochemical cell was initially created with an aluminum cathode and anode. Following that, each variable's impact was examined independently using synthetic wastewater. The colour removal efficiency was 93% when the initial dye concentration was 4 mg/L, the conductivity was 300 ppm, the temperature was 24 oC, the interelectrode spacing was 1 cm, and the HDT of the electrolysis was 120 min.

**Keywords:** ElectroCoagulation EC; Hydraulic Detention Time (HDT); Congo red dye ; Al electrode

**الخلاصة:** في هذه الورقة البحثية تمت دراسة إزالة صبغة الكونغو التفاعلية من مياه الصرف الصناعي باستخدام تقنية التخثير الكهربائي (EC). في محاولة لزيادة كفاءة الإزالة، تم التحقيق في آثار معاملات التشغيل بما في ذلك التدفق والمسافة بين القطبين، والتوصيل، والجهد، ووقت الاحتجاز الهيدروليكي (HDT). في البداية أنشئت خلية كهروكيميائية باستخدام قطب كاثود وأنود من الألومنيوم. بعد ذلك، تم فحص تأثير كل متغير بشكل مستقل باستخدام مياه الصرف الصناعي. كانت كفاءة إزالة اللون 93٪ عندما كان عند التدفق = 0.6 لتر / دقيقة، المسافة بين الاقطاب = 1 سم، NaCl = 300 ppm، الجهد = 30 فولت، و زمن الاحتجاز الهيدروليكي = (HDT) 120 دقيقة.

## 1. INTRODUCTION

The wastewater of the dyeing industry has long been regarded as one of the most important sources of pollution, not only because of its harmful chemical components, but also because of its colour. They may also interfere with the biological processes in the aquatic life. Additionally, because of the stability of their molecular structure, they are resistant to chemical or biological degradation. Therefore, in order to comply with the environmental requirements, the dye effluents should be treated before being discharged into the receiving water stream. [1,2]

These colours also degrade the quality of the receiving water, since many of the dyes emitted and their breakdown products are carcinogenic, poisonous, or mutagenic to the living things [3]. Azo dyes are the most often used dyes in the textile industry, accounting to 20-40% of the dyes used to colour silk, cotton, rayon, wool, leather, and nylon. The reactive dye is the most apparent among the categorised dyes because of its capacity to resist biodegradation. [4, 5, and 6]

In literature, there are many ways for removing colours from wastewater. Chemical coagulation, adsorption, chemical degradation, photo-degradation, precipitation, biosorption, biodegradation, membrane separation, accelerated oxidation, and electro coagulation are some of the techniques used. Most of these techniques are limited by difficulties in operation or costs, and although biological treatments are less expensive than other options, the toxicity of the dye inhibits bacterial growth, reducing its effectiveness in removing color. For physical methods, the additional chemicals required by these techniques often result in secondary pollution and large

amounts of sludge. Electrocoagulation technology has been shown to avoid most of these problems in wastewater treatment. [8]

Electro coagulation is a better method for treating dye-containing wastewater than traditional coagulation because it produces less sludge and does not produce pollutants like chloride or sulfate ions, making it environmentally friendly, simple, effective, and cost-effective. It can also remove tiny colloidal particles because the electric field controls particle motion. [9]

It involves the synthesis of coagulant in situ after metal cations are dissolved at the anode and hydroxyl ions and hydrogen gas are formed at the cathode. Waste water is cleaned of charged ionic species by reacting with coagulates of metallic hydroxide produced in effluent. The key steps of EC are as follows: 1. Electrolytic reactions at electrode 2. Coagulants Formation 3. Pollutants Adsorption and removal [10, 11]. Because aluminum, iron, and stainless steel are affordable, easily available, and non-toxic, they are often employed as electrodes. This is why, in the EC technique, they are frequently used as primary electrode materials [12].

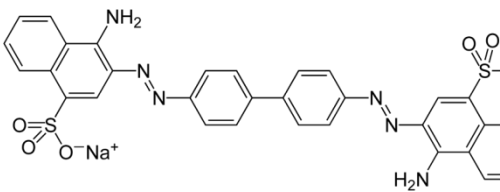
The purpose of this study is to investigate the decolourisation of reactive Congo red dye from aqueous solutions by electro coagulation process and to find the influence of HDT on dye removal relative to flow, distance between electrodes, NaCl concentration, and applied voltage. The optimal values of these factors are also estimated.

## 2. MATERIALS AND METHODS

### 2.1. Materials:

The dye used in the present study is the reactive Congo red dye. Table 1 describes the general characteristics of Congo red dye. In order to manufacture synthetic wastewater, 4 mg/L of the dye was dissolved in deionised water.

**Table 1.** General characteristics of Congo red dye.

parameter	value
Chemical formula	C <sub>32</sub> H <sub>22</sub> N <sub>6</sub> Na <sub>2</sub> O <sub>6</sub> S <sub>2</sub>
Chemical Dye class	Azo
Density ( gm/cm <sup>3</sup> )	4.25
Molecular weight, (g/mol)	696.665
Chemical Structure	

An electrical balance was used to weight the materials and NaCl to adjust the conductivity to the desired value. DC power supply with a current of (0-10) A and voltage of (0-30) V was used for the required voltage. At room temperature, a magnetic stirrer with (120 rpm) was used to mix the electro coagulation solution during the tests. The dye concentrations were measured by spectrophotometry with a UV-visible spectrophotometer (Spectro Direct-lovibond) as shown in Figure 1.



Figure 1. Spectro Direct-lovibond

## 2.2. Methodology ( Continuous Study )

The EC reactor was made of Perspex glass with dimensions (30 cm x 15 cm x 15 cm) (length, width, height) to perform simulated wastewater treatment experiments. Four pairs of (Al) plates with an active surface area of (108) cm<sup>2</sup> were used as positive electrodes and cathodes. The electrodes were kept 0.5 cm above the bottom of the EC reactor. Figure 2 shows the EC cell in adiagram.

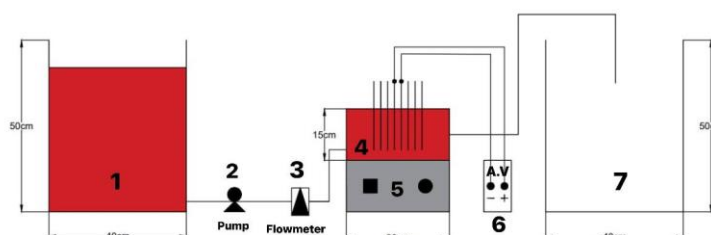


Figure 2.Schematic diagram of the E.C cell.1. Influent tank. 2. Pump. 3.Flometer. 4. EC cell with Four pairs of (Al) plates 5. magnetic stirrer 6. power supply . 7.Final storage.

Synthetic water was pumped from the feeding tank to the electric cell by the pump, and a flow meter was connected to the pump to pump out the required flow rate in each experiment. The experiments were performed in stages. One variable was adjusted at a time for each stage, and the best value was provided for the next section of the experiment, as shown in Table 2.

The water leaving the electric cell was collected in an external tank. Samples were taken from the cell port. Samples were collected from the reactor outlet every 30 minutes for 2 hours. During the experiments, a magnetic stirrer (120 rpm) was used to mix the electro coagulation solution at room temperature  $20 \pm 4$  °C.

To avoid passivation on the (Al) electrodes, the power supply was turned off at the end of each run. Then the electrodes were cleaned with a weak solution of hydrochloric acid. To remove the dyes from the water, a continuous flow reactor used atpresent work.Experimental work was planned to find the highest efficiency of dye removal.

**Table 2.** Continuous Study (experimental work).

Effect	Flow ( L/min)	Gab (cm)	NaCl (ppm)	Voltage (v)	Initial Dye conc. ( ppm)
Flow L/min	0.06 , 0.1, 0.15	1	100	10	4
Gab ( cm)	0.06	1,3, 5	100	10	4
NaCl (ppm)	0.06	1	100, 200, 300	10	4
Voltage (v)	0.06	1	300	10,20,30	4

## 2.3. Analytical Procedure

### 2.3.1. Hydraulic Detention Time (HDT)

It is the total time in minutes in which the coloured wastewater stays in the reactor. It can be defined as the proportion of the reactor's volume to its discharge, as shown in eq.1

$$HDT = \frac{\text{Reactor volum(L)}}{\text{Flow rate}(\frac{L}{min})} \quad (1)$$

### 2.3.2. Evaluation of Removal Efficiency

The efficiency of dye removal in the contaminated synthetic water treated with electrocoagulation is calculated as:

$$R \% = \frac{C_o - C_f}{C_o} \times 100 \quad (2)$$

Where:

R= dye removal efficiency.

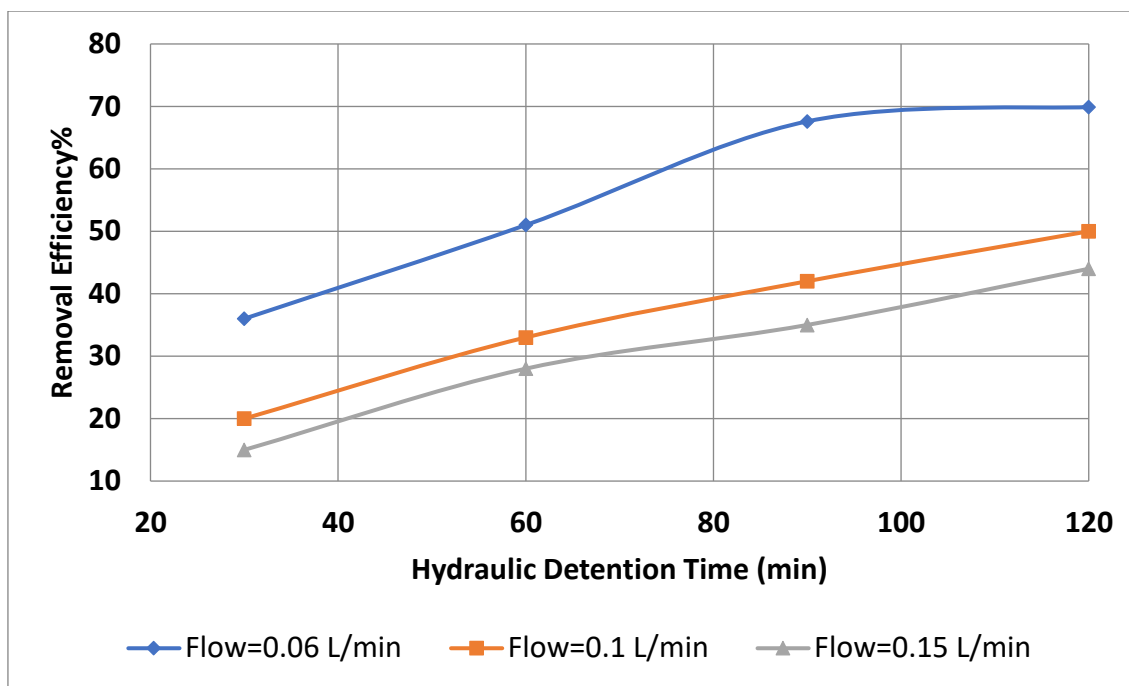
C<sub>o</sub>= First dye concentration (Pt-Co).

C<sub>f</sub>= final dye concentration (Pt-Co)

## 3. RESULTS AND DISCUSSIONS

### 3.1. Influence of HDT on Dye Removal Relative to Flow

The influence of HDT on the dye removal was studied with HDTs ranging from 30 to 120 min relative to applied flow (L/min). To investigate the effect of HDT, the flow rate was set at a certain value 0.06, 0.1, and 0.15 L/min while HDT was changed to 30,60,90 and 120 min. Figure 3 explains the effect of HDT on the efficiency of dye removal when the Gab = 1 (cm), voltage =10 V, NaCl = 100 (ppm), and the initial dye concentration = 4 (ppm).



**Figure 3.** Effects of flow on dye removal efficiency

Figure 3 shows that increasing HDT at a low flow rate resulted in a greater rate of dye removal efficiency. For example, at flow = 0.06 (L/min) and HDT= 30 min, the removal efficiency was = 36%. Whereas the removal efficiency increased to 69.9% when HDT was raised to 120 min.

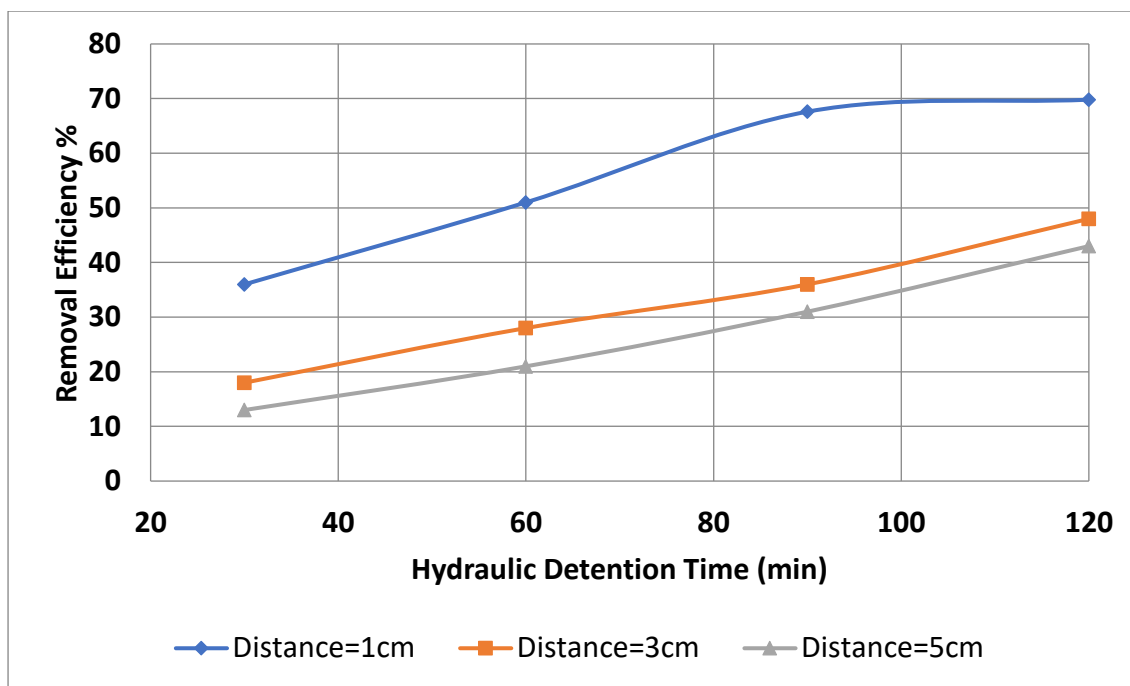
In actuality, because of the constant applied voltage the quantity of aluminum ions and hydroxides generated is constant at a specific time [13]. Table 3 explains the lower and higher applied flow rate effects on dye removal percentage at 30 and 120 min HDT.

**Table 3.** lower and higher applied flow rate effects on dye removal percentage at 30 and 120 min HDT.

HDT (min)	Flow rate = 0.06 L/min	Flow rate = 0.15 L/min
30	36%	1°%
120	69.9%	4ξ%

### 3.2. Influence of HDT on Dye Removal Relative to Electrodes Distance (Gab)

The effect of HDT on dye removal was studied in HDTs between 30 min to 120 min at different distances between the electrodes. To examine the effect of HDT, HDT was changed to 30, 60, 90 and 120 min at different studied spacing values which were 1, 3 and 5 cm, and the effect of HDT on the percentage of dye removal efficiency is shown in Figure 4, when flow = 0.06 (L/min), initial dye concentration = 4 (ppm), NaCl = 100 (ppm), and voltage = 10 (v).



**Figure 4.** Effects of electrode distance on dye removal efficiency

Figure 4 shows that the decrease in the concentration of the dye effluent was caused by an increase in HDT over low electrode distance (i.e., greater removal rate). Illustrating this, at electrode distance = 1 cm, the dye removal efficiency = 36% at 30 min, while the removal efficiency rose to 69.9% when the HDT was raised to 120 min.

It is important to run the EC process at the optimum spacing between the electrodes. By keeping the electrodes at their ideal distance from one another, maximum pollution removal efficiency may be achieved. The increase in the electrode distance over the optimal level limits the effectiveness of pollution removal. This is due to the fact that as the distance between the electrodes increases, so does the journey time of the ions. Additionally, the electrostatic attraction is lessened, which reduces the requirement for flocs to develop in order to coagulate the contaminants [14]. Table 4 shows the effect of the lowest and highest electrode distance on dye removal at 30 and 120 min HDT.

**Table 4.** lower and higher electrode distance on dye removal at 30 and 120 min HDT.

HDT (min)	electrode distance = 1cm	electrode distance =5cm
30	36%	13%
120	69.9%	43%

### 3.3. Influence of HDT on Dye Removal Relative to NaCl

The impact of HDT on dyeremoval was studied with HDTs ranging of (30–120) min. To investigate the effect of HDT, NaCl was fixed at a certain value 100,200,and 300 ppm, while HDT waschanged to 30,60,90 and 120 min. Figure 5 explains the effect of HDT on the efficiency of dyeremoval, when the flow = 0.06 (L/min), Gab =1(cm),initial dye concentration= 4 (ppm), and Voltage =10 (v).

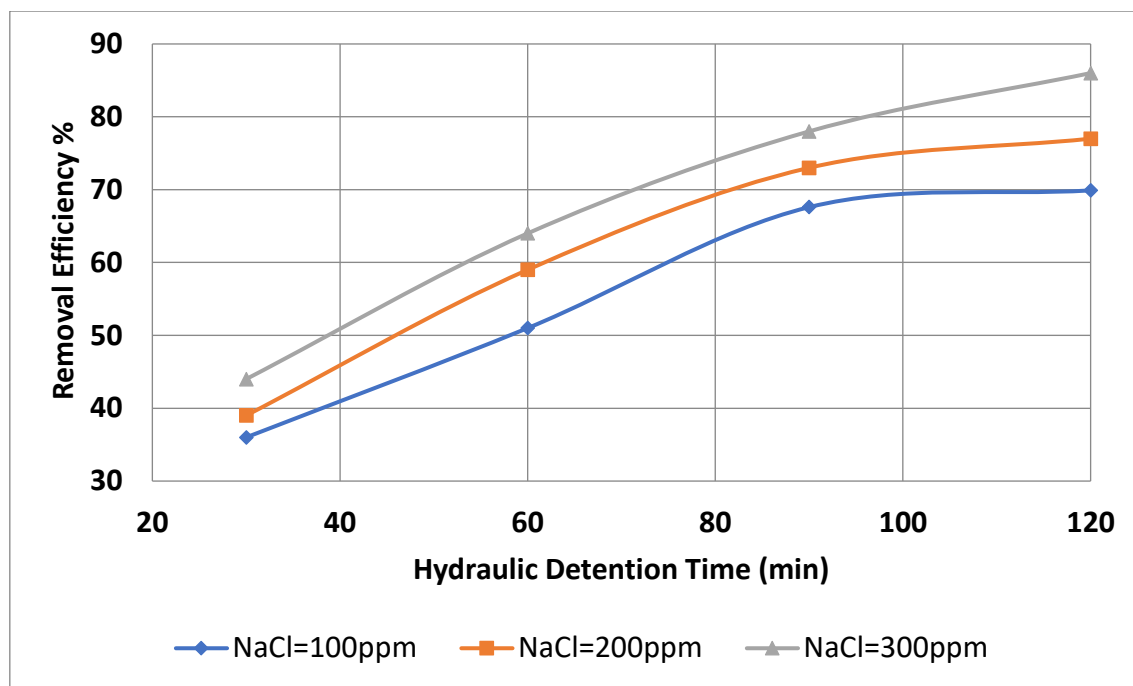


Figure 5. Effects of Sodium Chloride ( NaCl ) on dye removal efficiency

It is observed from Figure 5 that at high conductivity, the increase of HDT resulted a higher removal efficiency. For instance, at NaCl= 300 ppm, efficiency of dye removal = 44 % at 30 min. Whereas the removal efficiency raised to 86 % when HDT was raised to 120 min.

NaCl is typically added to solutions to improve electrolytic conductivity.  $Cl_2$  and  $OCl^-$  are the byproducts of the anode when chlorides are present in the solutions. Being a potent oxidant in and of itself,  $OCl^-$  has the ability to oxidise any dye molecules present in the solution[15].Table 5 explains the lower and higher NaCl effect on dye removal percentage at 30 and 120 min HDT.

Table 5. lower and higher NaCl effect on dye removal percentage at 30 and 120 min HDT.

HDT (min)	NaCl= 100 ppm	NaCl =300 ppm
30	36%	44%
120	69.9%	86%

### 3.4. The Effect of HDT on Dye Removal in Relation to Applied Voltage (V)

The influence of HDT on dye removal relative to applied voltage (V) in solutions of HDTs from 30 to 120 min and the impact of HDT on removal of dye were studied. To investigate the effect of HDT, the voltage was set at a certain value 10,20,and 30V while HDT was changed to 30,60,90 and 120 min. Figure 6 explains the effect of HDT on the efficiency of dye removal when the  $G_{ab} = 1$  (cm), flow =0.06 (L/min), NaCl = 300 (ppm), and initial dye concentration = 4 (ppm).

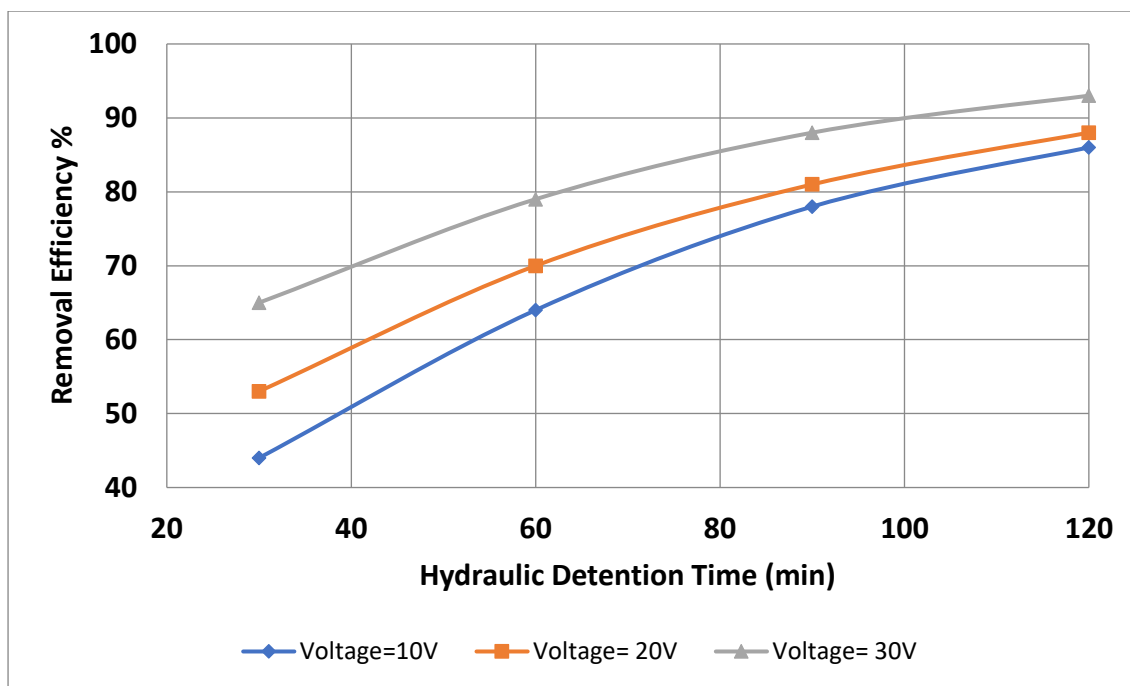


Figure 6. Effects of voltage on dye removal efficiency

It is noted from Figure 6 that more applied voltage led to high dye removal efficiency with a rise in HDT, when V= 30 volts and HRT= 30 min the dye removal efficiency = 65 %. Whereas the dye removal efficiency increases to 93% when HRT was raised to 120 min. Actually, the provided voltage controls the rates of coagulant dosing and bubble generation, as well as the solution mixing and mass transfer at the electrodes[16].Table 6 explains the lower and higher applied voltage effects on dye removal percentage at 30 and 120 min HDT.

Table 6. lower and higher applied voltage effects on dye removal percentage at 30 and 120 min HDT.

HDT (min)	V = 10 v	V=30 v
30	44%	65%
120	86%	93%

#### 4.CONCLUSION

In EC, the optimisation of operational parameters are important considerations for the evolution of the process. In this work, it was observed that these variables significantly affected the removal efficiency of Congo red dye. The optimum Congo red dye removal efficiency 93 % was obtained at a decreasing flow,less inter electrode distance, high NaCl concentration, and at increasing of voltage.EC was proved to be an active method for the removal of color from simulated wastewater from the reactive Congo red dye. It can be concluded that electro coagulation process is a simple technique that can be used as an effective and affordable method to remediate effluents that are dyestuff-contaminated.

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