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Electrocoagulation process for textile wastewater treatment in continuous upflow reactor

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This study investigates the influence of operating parameters (current density, detention time and time of electrolysis) on COD and color removals from a simulated basic dyebath effluent using electrocoagulation (EC) with iron electrodes in continuous flow mode. Till today, researchers are mainly focused on use of EC systems in batch processes. Looking to large quantities of wastewater from textile Industry, continuous flow regime may offer a better solution. Firstly, the operational parameters including current density (*j*), detention time (DT) and time of electrolysis were optimized. Then, total electric work (E) and sacrificial weight of anode were calculated under optimum conditions. The size of electrode plate (5cm*5cm*0.5cm, 124cm^2) was kept constant for all sets of experiments. Our results indicated that for a solution of 300mg/L basic red *dye 5001 B*, almost 76% COD and 95% color were removed, when the pH was about 9, the DT was 20 min and the *j* was 14-17 mA/cm^2. Pseudo steady-state was achieved after passing 60 minutes of current in the solution. In addition, the result of our study indicates that when the *j* and DT was increased above optimum level, charge reversal and surface saturation was occur due to the excessive addition of coagulant.

Keywords: Electro coagulation, textile wastewater, up flow reactor, COD removal, current density.

Introduction

Textile industries are among the most polluting industries in terms of the volume and complexity of treatment of its effluent discharge. Textile industries consume large volumes of water and chemicals for wet processing of textiles. Textile mill effluents are also characterized by high levels of color caused by residual dyes, COD, salt content, high temperature and broad ranges of *p*H[1]. The colored wastewater released into the ecosystem is also a dramatic source of aesthetic pollution and perturbation in the aquatic life[2]. Furthermore, dye effluents can contain chemicals, which are toxic, carcinogenic, or mutagenic to various microbiological or animal species[3].

Treatment of dyed wastewater can be take place by many types of conventional method such as biological treatment, chemical coagulation, activated carbon adsorption, ultrafiltration, ozonation and electro-coagulation–electroflotation[4] (EC–EF). Each treatment method has its own advantages and disadvantages. EC has been recently gained more interest when biological treatments fail, while it avoids the formation of secondary pollutants[5]. The contaminants present in wastewater are stabilized in solution by electrical charges. When metal ions (trivalent ions in most cases) provided by EC are neutralized with ions of opposite electric charge of the suspended matters they become unstable and precipitate to solids of a high stability[6]. The electrochemical process appears as ideal to take advantage of the combined production of polyvalent cations by oxidation of sacrificial anodes e.g. Fe and Al, and flotation of the pollutants to the solution surface where it can be more easily collected and removed. The metal ions can react with the OH^- ions produced at the cathode during gaseous H_2 evolution, to yield insoluble hydroxides which adsorb pollutants out of the solution. It also contributes to coagulation by neutralizing the negatively charged colloidal particles which have been reported to be more compact than sludge obtained by chemical methods.

The most widely used electrode materials in EC process are aluminum and iron[1]. In this study, basic

Abbreviations

COD	Chemical Oxygen Demand
DT	Detention time (min.)
EC	Electrocoagulation
EF	Electroflotation
I	Current (A)
j	Current density (mA/cm^2)
Y_{COD}	COD removal efficiency

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red *dye 5001 B* was used which is basic in nature and iron electrode performs better EC at basic pH[7]. The results of these works show that COD, color, turbidity and even dissolved solids can be efficiently removed using EC[4,5,7-12]. The continuous regime of the EC process has however been less investigated, except in a few studies[13-16], especially in the case of COD reduction.

Most of the studies available in the literature are based on batch flow reactor. Textile industry is water based industry which discharges large quantities of waste water. In our opinion, a batch flow reactor will not offer feasible solution for such large quantity of wastewaters. The prime objective of this study was to determine the feasibility of EC in the continuous flow regime to treat a wastewater, which was simulated, according to the wastewaters released from a Sanganer industrial area, Jaipur, India. The effluent released from these industries slowly infiltrates into the land and finds its way to the ground water table, thereby making it unsafe for drinking and other domestic purposes. Further, effects of various operating parameters on efficiency of EC process in continuous flow regime were determined.

Materials and methods

Reactor design

The experimental set up used in this study consists of a beaker of 2.0 liters as a reactor to hold a sample of 1500 ml. A pair of rectangular iron plates was used as anode and cathode at a spacing of 4 cm. Weight of electrodes was taken and by the help of this sacrificial weight of electrodes was calculated. EC unit was fed continuously with a peristaltic pump (Miclins, pp-20-EX; 2ml/h to 10 L/hr) using the effluent from a wastewater tank (Fig. 1). EC unit was connected to the DC linear power source (Testronix, 92-D; 30 V and 10 A). All the experiments were conducted at room temperature with water temperature varying in a close range of 25-27°C.

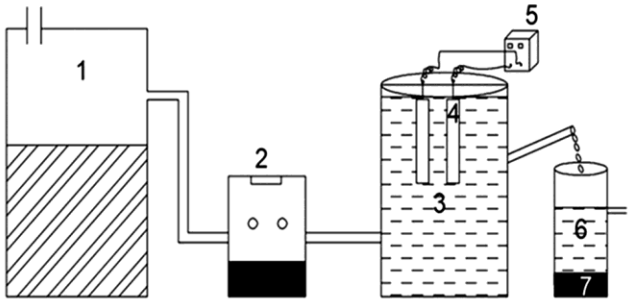

Fig. 1—Experimental setup of continuous EC cell (1: wastewater tank; 2: peristaltic pump; 3: inlet of the first compartment; 4: electrodes; 5: DC power supply; 6: treated effluent outlet; 7: sludge).

Preparation of simulated waste water

Experiments were carried out on synthetic wastewater samples consists of 300mg/L basic red *dye 5001 B* (commercial name of a direct dye used extensively in the region), 3gm/L NaCl, 5.56 mg/L hydrolyzed starch, 11.12 mg/L ammonium sulphate, 11.12 mg/L disodium hydrogen phosphate, 7-8 drops liquid detergent. Synthetic wastewater was prepared by mixing all the chemicals in tap water and heated at 80°C for 1.5 hours to stimulate the actual wastewater, which was then left to cool to room temperature[9]. The physicochemical characteristics of simulated wastewater were tabulated in Table. 1. All the chemicals used during experiment were purchased from Merck. All experiments were done in duplicates and average values were taken.

During the experiments, voltage was used as operating parameter and corresponding current was recorded and on the basis of recorded current, *j* was calculated. The *j* was calculated through the equation as follows:

$$j = \text{I (A)} \div \text{S.A. (cm}^2\text{)} \quad \ldots (1)$$

Where I = Current (A) and

S = Surface area of the electrode (cm^2)

COD of treated effluent was measured at an interval of consecutive 10 minutes till the pseudo steady state was achieved. Pseudo steady state was characterized by variation of less than 5% in three consecutive readings of effluent COD. COD was measured by closed reflux calorimetric method with absorbance being measured at 600 nm using UV/VIS spectrophotometer (Schimadzu, UV-240). COD removal efficiency (Y_{COD}) was expressed as a percentage removal.

Electrodes having an area of about 124.4 cm^2 were used to assess the feasibility of COD removal at

Table 1—Physicochemical characteristics of simulated wastewater

S.No.	Parameter	Average Values
1.	*p*H	9
2.	COD (mg/l)	600-650
3.	Temperature (^{0}C)	25-27^{0}C
4.	Color	Dark orange
5.	Conductivity (mS cm^{-1})	4.7

20, 30 and 40 minutes of DT. Before each run of experiment, electrodes were washed with acetone to remove surface grease, and the impurities from the iron electrode surfaces was removed by dipping them for 5 min in a solution freshly prepared by mixing 100 cm^3 HCl solution (35%) and 200 cm^3 of hexamethylenetetramine aqueous solution (2.8%)[7]. Sacrificial weight of electrodes were calculated by measuring their weight before and after of EC process.

Results and Discussions

Effect of current density and operating time on COD removal efficiency

It is well known that *j* is the major operating variable directly affecting the performance of electro coagulation and operating costs. It is clearly evident that as the value of *j* increases from 7.55-17 mA/cm^2 a substantial increment in the Y_{COD} was observed (Fig. 2). Highest removal efficiency was achieved at 14-17 mA/cm^2. This may be due to as the value of *j* increases, the amount of Fe^{3+} cations released by the anode increases and therefore formation of monomeric ions and hydroxyl complexes increases[1]. These hydroxides complexes have strong affinity with dispersed, dissolved as well as counter ions to cause coagulation and adsorption. But, it doesn't mean that Y_{COD} was directly proportional to *j*. The decrement in Y_{COD} with increased *j* was also observed at 20.0-23.0 mA/cm^2. This may be attributed to the adsorption of the hydrogen bubbles produced by the electrodes, although the cathode was perforated, hydrogen bubbles adsorb on the lower face of cathode and remain blocked on this area[1]. This technical problem induces a reduction in the Y_{COD} as the *j* was increases. Another limitation of working at high *j* was that no increment observed in the Y_{COD}. Indeed, electrode material consumption increases as a factor of *j* while energy consumption rises as j^2 and induces heating by joule effect[1].

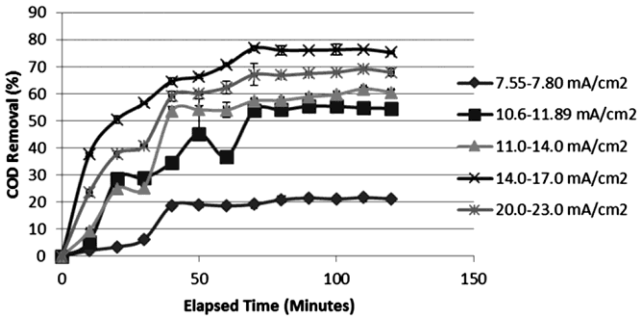

Fig. 2—COD removal profile at different current density (*j*): *C*i = 300 mg/L, influent pH=9, k = 4.7 mS/cm.

During electrolysis, the positive electrode undergoes anodic reactions while cathodic reactions occur on the negative electrode. The released ions neutralize the particle charges and thereby initiate coagulation. The Y_{COD} depends directly on the concentration of ions produced by the electrodes as the time of electrolysis increases. After passing 60 minutes of current in the solution almost stable pseudo steady state was achieved in different *j* and thereafter only ± 5% Y_{COD} was achieved (Fig. 2).

Effect of detention time on COD removal efficiency

In order to find out the optimum DT for treatment of simulated wastewater at which maximum COD removal was achieved-the inlet flow rates were progressively varied to achieve designated DT of 20, 30 and 40 minutes. The continuous EC process provided an Y_{COD} higher than 50% for all the studied DT at 14-17mA/cm^2 of *j* (Fig. 3). Although, it was reported in this study as the DT increases, Y_{COD} decreases and there may be two possible reasons. First, the excessive addition of counter ions from coagulant (iron) may result in restabilization by a charge reversal; the net charge on the particles may be reversed by the adsorption of an excess of counterions. Second, the particles restabilization, if there was an insufficient number of a colloidal particle available for bridging or due to surface saturation or sterical stabilization[17]. In studied process, complete decolurization was achieved within 20 minutes at all the considered detention time (data not shown here). In comparison for the complete decolourization and 85 % of COD removal, Fenton process takes 40-120 min[18]. Although, Fenton process was highly sensitive to pH change and reagent dosage but electrocoagulation was not. Thus, it concluded that maximum COD removal was achieved at about 20 min DT at 14-17mA/cm^2 of *j*.

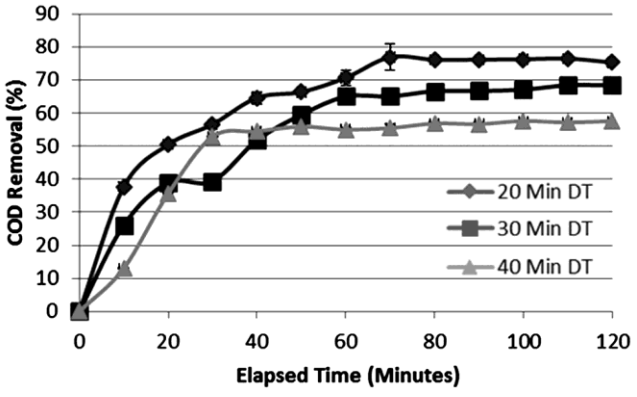

Fig. 3—Effect of detention time on COD removal profile: *j* = 14-17 mA/cm^2, *C*i = 300 mg/L, influent pH=9, k = 4.7 mS/cm

Conclusion

Day by day regulations becoming increasing stringent, industrial users are searching for more advanced method to solve their wastewater treatment problems. EC is one of the most promising techniques for the treatment of wastewater containing color and organic pollutants. The COD and color removal of dye solution of basic red *dye 5001 B* was affected by *j*, DT and time of electrolysis. Our results showed that unilateral increase in *j*, DT, and time of electrolysis would not assure higher COD removal, and an optimization of these parameters must determine to achieve the optimum COD removal for a given type of wastewaters. For a solution with dye concentration of 300mg/L, COD and color elimination of 76% and 95%, respectively were reported, when the *p*H was about 8.5, the DT 20 min and the *j* 14-17 mA/cm^2. In addition of these, the result of our findings indicates that when the DT and *j* was increased above optimum level, charge reversal and surface saturation were occur due to the excessive addition of coagulant. Complete color removal was achieved after 15-20 min of detention time.

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References

1 Mohan N, Balasubramanian N & Subramanian V, Electrochemical Treatment of Simulated Textile Effluent, *Chem Eng & Tech,* **24** (2001) 749-753.

2 Sevimli M F & Sarikaya H Z, Ozone treatment of textile effluents and dyes: effect of applied ozone dose, pH and dye concentration, *J Chem Tech & Biotech,* **77** (2002) 842-850.

3 Greaves A J, Phillips D A S & Taylor J A, Correlation between the bioelimination of anionic dyes by an activated sewage sludge with molecular structure. Part 1: Literature review, *Color Tech,* **115** (1995) 363-365.

4 Kobya M, Can O T & Bayramoglu M, Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes, *J Haz Mater,* **100** (2003) 163-178.

5 Alinsafi A, Khemis M, Pons M N, Leclerc J P, Yaacoubi A, Benhammou A & Nejmeddine A, Electro-coagulation of reactive textile dyes and textile wastewater, *Chem Eng Process,: Proc Intens,* **44** (2005) 461-470.

6 Merzouk B, Gourich B, Sekki A, Madani K, Vial Ch. & Barkaoui M, Studies on the decolorization of textile dye wastewater by continuous electrocoagulation process, *Chem Eng J,* **149** (2009) 207-214.

7 Kim T H, Park C, Shin E B & Kim S, Decolorization of disperse and reactive dyes by continuous electrocoagulation process, *Desalin,* **150** (2002) 165-175.

8 Slokar Y M & Majcen L M A, Methods of decoloration of textile wastewaters, *Dyes Pigm*, **37** (1998) 335-356.

9 Chen X, Chen G & Yue P L, Investigation on the electrolysis voltage of electrocoagulation, *Chem Eng Sci,* **57** (2002) 2449-2455.

10 Chen X, Chen G & Yue P L, Separation of pollutants from restaurant wastewater by electrocoagulation, *Sep Pur Tech*, **19** (2000) 65-76.

11 Mansour L B, Ksentini I & Elleuch B, Treatment of wastewaters of paper industry by coagulation-electroflotation, *Desalin,* **208** (2007) 34-41.

12 Mameri N, Yeddou A R, Lounici H, Belhocine D, Grib H & Bariou B, Defluoridation of septentrional Sahara water of north Africa by electrocoagulation process using bipolar aluminium electrodes, *Water Res,* **32** (1998) 1604-1612.

13 Daneshvar N, Ashassi S H & Tizpar A, Decolorization of orange II by electrocoagulation method, *Sep Pur Tech,* **31** (2003) 153-162.

14 Daneshvar N, Ashassi S H & Kasiri M B, Decolorization of dye solution containing Acid Red 14 by electrocoagulation with a comparative investigation of different electrode connections, *J Haz Mater,* **112** (2004) 55-62.

15 Mollah M Y A, Pathak S R, Patil P K, Vayuvegula M, Agarwal T S, Gomes J A G, Kesmez M & Cocke D L, Treatment of orange II azo-dye by electrocoagulation (EC) technique in a continuous flow cell using sacrificial iron electrodes, *J Haz Mater,* **109** (2004) 165-171.

16 Metcalf & Eddy, *Wastewater Engineering Treatment and Reuse*, Washington, Seattle, **4th ed,** (Tata McGraw-Hill) 2003, 478-493.

17 Kang S F, Liao C H & Chen M C, Pre-oxidation and coagulation of textile wastewater by the Fenton process, *Chemosphere*, **46** (2002) 923-928.