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Effect of modification of textile wastewater composition on electrocoagulation efficiency

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ABSTRACT

This paper deals with the efficiency of electrocoagulation (EC) for the abatement of COD, TOC, absorbance (i.e. color) and turbidity from a real textile wastewater, a pure red dye solution (disperse dyes 2-naphthoic acid and 2-naphthol) and a solution combining the two above fluids. The treatment of the dyestuff solution is satisfactory with high levels of color and organic pollution abatement. The treatment of the industrial waste is less efficient. Treatment of the solution combining the two above fluids allows to investigate whether the removal of several polluting matters by electrocoagulation could be considered as the superimposition of the various treatments of single-species effluents, in sort of additivity principle, as presented in an original model for the treatment of two-pollutant waste. Turbidity and TOC were shown to be additive variables in the treatment of the dye solution and the industrial textile waste: electrocoagulation seems to proceed with no interaction between the two types of matter to be removed, namely the dye stuff, and the lot of pollutants contained in the industrial waste.

1. Introduction

Electrocoagulation is an effective primary treatment for highly polluted industrial wastewater. It has been used successfully for the treatment of various industrial effluents including effluent issues from food industries [1,2], tanneries [3,4], heavy metals [5–8], mechanical workshop (soluble oil) [9,10], polymerization manufactures, and textile industries [11–14]. Its application for the treatment of textile wastewaters is of a primary interest for two main reasons. The first one is that this treatment is very efficient and adapted for wastewaters containing high level of various types of pollutants (organic, mineral, heavy metals, and dyes…). Secondly electrocoagulation is known for its high efficiency in decolorization. Numerous papers are therefore devoted to decolorization of solutions prepared with specific dyestuffs as illustrated by the general review recently published by Martĩnez-Huitle and Brillas [15]. In most cases, each paper is focused on one specific dye dissolved in pure water: the effects of various operating parameters e.g. pH, initial concentration, current density, electrode gap on the removal efficiency have been investigated, in particular regarding the COD level and the absorbance at the maximum wavelength. Very satisfactory results are usually reported, with color removal efficiency ranging between 98% and 100% in most cases.

Ayhan et al. [16] have studied the decolorization of a synthetic wastewater containing C.I. Reactive Black 5 in a batch reactor with an electrode gap at 2.5 cm. They observed that the color caused by 100 mg L^{-1} dyestuff was removed effectively up to 98.8% at ambient temperature using iron electrodes for an initial pH at 5, with a current density of 4.575 mA cm^{-2} and in the presence of 3 g L^{-1} NaCl. The kinetics of decolorization followed by spectrophotometry, was shown to obey a first-order law. First-order kinetics has been also found by El-Ashtoukhy and Amin [17] for decolorization of Acid Green dye 50. Several studies have aimed at finding optimal operating conditions for color removal of specific dyestuffs e.g. crystal violet [18], orange II [19] or C.I. Acid Red 14 azo dye [20]. The optimal initial pH is often reported to be near 7, whereas the time of treatment and the current intensity are linked together. This is because the key parameter is in fact the quantity of electrogenerated coagulant, which actually varies with the integral of the current over time. Zhang et al. [21] studied the decolorization of C.I. Acid Red 2 using carbon steel anodes and stainless steel cathodes. IR spectra interpretation revealed that in addition to the coagulation process, breaking of the C—N bond occurs. This cleavage is not due to a direct oxidation of C.I. Acid Red 2 on the anode surface but occurrence of indirect oxidation of C—N containing organic species by ferric ions can be supposed. Daneshvar et al. [22] obtained color elimination of 99% of C.I. Acid Yellow 23 solution, but a

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COD elimination of 69% only. This result shows that absorbance is not sufficient to estimate the efficiency of the treatment since the decolorization may be due to bond cleavage, leading to a recalcitrant pollution sometimes more serious than that caused by the initial dye [23,24].

A very interesting study on the effect of dye auxiliaries on color removal has been carried out by Kabdaşli et al. [25] using a synthetic reactive dye bath composed of three elementary dyes (Reactive Red confidential Color index, Reactive Yellow 145 and Reactive Blue 221) with additions of NaCl, Na_2CO_3 or polycarboxylic acid. Color and COD removal are well represented by first-order kinetics for both stainless and aluminum electrodes. Addition of Na_2CO_3 and polycarboxylic acid has a negative impact on the color and COD removal whereas the addition of NaCl improves the efficiency of the treatment especially when aluminum electrodes are used.

More recently, Phalakornkule et al. [26] studied – in terms of absorbance only – the treatment of separate dyestuffs (blue reactive and red disperse), then the treatment of a liquid prepared from a textile wastewater with addition of the two dyestuffs. High removal of color could be easily reached with the synthetic solutions, whereas treatment of the colorized wastewater was observed to be less efficient.

As illustrated by the relevant literature, the mechanism of decolorization of specific dyes has been extensively studied. However, the effluents issued from textile industry contain a broad spectrum of different dyes mixed together and their composition can vary according to the customer's orders, fashion and period of the year. Several papers pointed out the necessity of studying the electrocoagulation efficiency in different types of synthetic textile effluents and real complex effluents [27,28]. In this regard, the objective of the paper is thus to study the treatment of a given industrial effluent in terms of color, turbidity, COD and TOC, with examination of the possible changes induced by a composition modification. Does electrocoagulation proceed in mixed effluents according to simple superimposition of the treatment of single wastes, or is there any synergetic/inhibiting effect of one polluting matter on the others in the waste treatment process? For this purpose three wastewaters have been treated by electrocoagulation process: a pure red dye solution, a real industrial wastewater issued from a textile plant, and the above waste colorized with the red dye.

2. Materials and methods

2.1. Chemicals and analytical techniques

Experiments were carried out using a red dye solution, a textile effluent issued from DMC, a textile industry, St. Amarin, France, and this waste after addition of the above dyestuff. The industrial waste was already used in previous investigations [14]. The red dye solution was prepared by mixing 2-naphthoic acid and 2-naphthol (Fig. 1) with a total concentration (C_0) of 100 mg L^{-1} in pure water. High purity NaCl at 1 g L^{-1} was added for sufficient conductivity of the obtained solution. The ionic charge of industrial waste rendered unnecessary the addition of sodium chloride.

Dye concentration was estimated from its absorbance characteristics in the UV–vis range (250–800 nm), using the wavelength that provided the maximum intensity ($\lambda_{max} = 503$ nm) and a UV–vis spectrophotometer (Secomam). The absorbance of the initial solution near 0.2 was in the order of that in industrial dyestuff-containing wastes. The absorbance of the textile waste was measured at the dominant wavelength at 260 nm ($\lambda_{max} = 260$ nm); this wavelength was found to be suitable for the mixed dye-textile waste. Solution conductivity and pH were measured using a CDM210 conductimeter and a Consort C832 pH-meter respectively. The COD levels were determined using the standardized colorimetric method with excess of hexavalent chromium and subsequent measurement of the optical density. TOC determination was carried out with a TOC-V(CPH) Shimadzu Total Organic Carbon Analyzer. Turbidity of the waters was measured using a Hanna Ins. LP 2000 spectrophotometer. Data were given in Nephelometric Turbidity Unit (NTU).

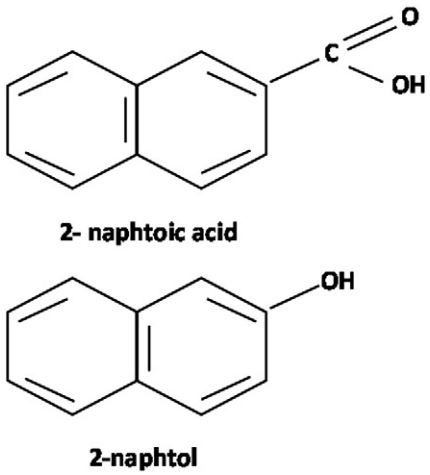

Fig. 1. Molecular structure of the constituents of the red dye 14.

The physicochemical features of the three solutions to be treated are reported in Table 1.

Concentrations of Al were determined by atomic absorption (Varian AA-20), after dilution and acidification of the solution samples with nitric acid for total dissolution of the metal species. In most cases, the liquid fractions had to be filtered using conventional 0.45 μm filters to remove the suspended solids, prior to injection into the atomic absorption apparatus.

2.2. Set-up and protocol

The batch experimental set up is shown in Fig. 2. The EC cell was a parallel plate electrochemical cell out of methyl polymethacrylate provided with two facing electrodes machined in aluminum. Two aluminum electrodes of rectangular shape (150 mm × 70 mm × 10 mm), have been used as anode and cathode, which correspond to $S = 105$ cm^2 electrode surface area. The distance between the two electrodes was $e = 20$ mm. These were treated with an HCl aqueous solution for cleaning before use to avoid passivation. Experiments were conducted batchwise with recirculation of the liquid in the circuit, which consists of a peristaltic pump, the cell and a double-walled tank for temperature control at approx. 20 °C and separation of the gas formed. Two liters of wastewater were introduced in the tank and a gentle agitation was ensured along the run. The flow rate of the liquid was fixed at 0.15 L min^{-1}. The current density was fixed in the range 40–200 A m^{-2} using an AFX 2930 SB DC power supply and the cell voltage was continuously recorded. Twenty-cubic centimeter samples were taken during the 1-h long runs for assessment of the treatment progress as follows. The pH was observed to increase regularly from its initial value, depending on the current density applied. The pH of the samples was adjusted to 7 within 0.5 for optimal precipitation of Al hydroxides.

Table 1
Physicochemical features of the wastewaters considered.

Characteristics	Red dye solution	Industrial waste	Dyed industrial waste
pH	7.8	7.2	7.6
Absorbance	0.19	0.92	0.97
Turbidity (NTU)	14.7	23.9	32.7
COD (mg O_2 L^{-1})	27.2	1065	1357
TOC (mg L^{-1})	7.72	354	369
Conductivity (mS cm^{-1})	2.4	2.6	2.8