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Potential use of clay in electrocoagulation process of textile wastewater: Treatment performance and flocs characterization

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ABSTRACT

The present work deals with pretreatment of synthetic effluents in a batch stirred electrocoagulation cell with aluminum electrode coupled with adsorption using clay particles. Several working parameters such as pH, current density, clay dosage and operating time were studied in an attempt to achieve higher removal efficiency. The toxicity was also monitored by the *Daphnia magna* inhibition test. Results obtained with synthetic wastewater revealed that most effective color and COD removal capacities could be achieved without changing the pH. In addition, increasing current density in a range of 8–140 A/cm^2 and operating time from 2 to 15 min enhanced the treatment efficiency. The addition of clay as adsorbent resulted in remarkable increase in the removal rate of color and COD at lower current densities and operating time, than the conventional electrocoagulation process. The method was found to be highly efficient and relatively fast compared to existing conventional techniques.

1. Introduction

Textile wastewater is a major water pollution source in developing countries and often contains high concentrations of unfixed dyes (about 20%). Azo dyes are of great concern because of their widespread use, toxic aromatic amine intermediates, and recalcitrance for aerobic wastewater treatment [1]. Several techniques have been applied to remove dyes from wastewater, including adsorption, chemical oxidation, electrochemical degradation, and advanced oxidation processes. However, their low removal abilities or high costs often limit their application [2,3].

Electrocoagulation (EC) has been successfully employed for the removal of metals [4], hardness from drinking water [5], textile wastewater [6]. In this process, treatment is done without adding any chemical coagulant or flocculant, the coagulating ions are produced in situ involving three successive stages: (i) formation of coagulants by electrolytic oxidation of the "sacrificial electrode", such as aluminum, (ii) destabilization of the contaminants particulate suspension and breaking of emulsions, (iii) aggregation of the destabilized phases to form flocs as shown in Fig. 1 [6].

On the other hand, natural mineral clays possess specific surface chemical properties, e.g., cations exchange capacity, and adsorptive affinity for some organic and inorganic compounds, which have led to investigations on the potential use of clays as adsorbents for treating heavy metals and organic pollutants, or as coagulant aids [7,8]. Due to the above reasons and the abundance in Morocco, clay has been used as adsorbent. As a result of the operational difficulties and high cost of treatment of electrocoagulation for large-scale treatment of wastewater in developing countries like Morocco [9], adsorption process using low cost adsorbents has been coupled with electrocoagulation in this present study. Unlike other attempts, we have chosen to study the effect of adsorption in enhancing the process of treatment when coupled with electrocoagulation (EC). The influence of pH, current density, and treatment time and clay dosage on the treatment efficiency is explored.

2. Materials and experimental procedures

The basic raw clay, labeled NC, was from a Mio-Pliocene deposit sited at the east side of the high Atlas Mountain (Morocco) [10]. It looked like a fuller's earth and was used in rustic cosmetic preparations. Its fine fraction (equivalent spherical diameter <2 μm) represented 90%. The specific surface area determined by BET (Brunauer–Emmett–Teller-method) was 130 m^2/g. The SEM micrograph and EDAX analysis are given in Fig. 2.

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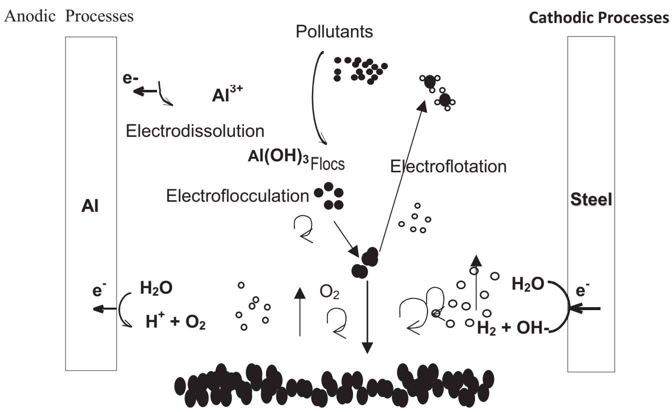


Fig. 1. Main stages involved in the electrochemically process using aluminum anodes.

The dye used in the experiments was reactive violet 4 (Table 1). Synthetic textile wastewater was obtained by dissolution of hydrolysed dye, hydrolysed starch (2.78 mg/L), $(NH_4)_2SO_4$ (5.56 mg/L) and Na_2HPO_4 (5.56 mg/L) in deionized water. Hydrolysis was performed by heating the solutions at 80 °C for 1.5 h. All chemicals and dye used in the preparation of the synthetic wastewater were supplied by a textile industry located in El Jadida (Morocco) and were used as received.

The experiment was performed in Pyrex reactor that consisted of a 0.3 L capacity, equipped with a cathode and an anode. The distance between the electrodes was 1 cm, and the total effective electrode area is calculated to be 20 cm^2, consisting of a sacrificial aluminum anode. The electrodes were dipped into the beaker containing wastewater with a 0.2 L working volume. The raw clay was admitted to the system at varying dosages. All experiments were repeated twice, and the experimental error was around 3%.

All electrochemical experiments were performed under fixed temperature 25 °C and under agitation speed of 200 rpm. After each test, the electrodes are cleaned daily with 0.1 M HCl and immersed in a solution of KCl 3 M and several times with deionized water. The electrodes were connected to a DC Power Supply 0–40 V, I_{max} = 0.9 A.

3. Analytical procedures

After settling, samples were taken at a 3 cm depth below the surface of the liquid, and analyzed for various physicochemical parameters like pH, color, electrical conductivity (EC) and chemical oxygen demand (COD), according to standard methods [11]. The residual aluminum concentrations were analyzed by atomic absorption spectrophotometry. The volume of decanted sludge is estimated by the volumetric method using the Imhoff cones [12]. Once the experiment has been performed, the beaker contents are transferred to special graduated conical containers (Imhoff cones). After 1 h of settling, the sludge production is determined by direct reading as ml of sludge/L of wastewater treated. Then it was analyzed by scanning electron microscopy (SEM) equipped with an EDAX spectrophotometer. The characteristics of the sludge produced were measured in terms of cake solid concentration and other related parameters.

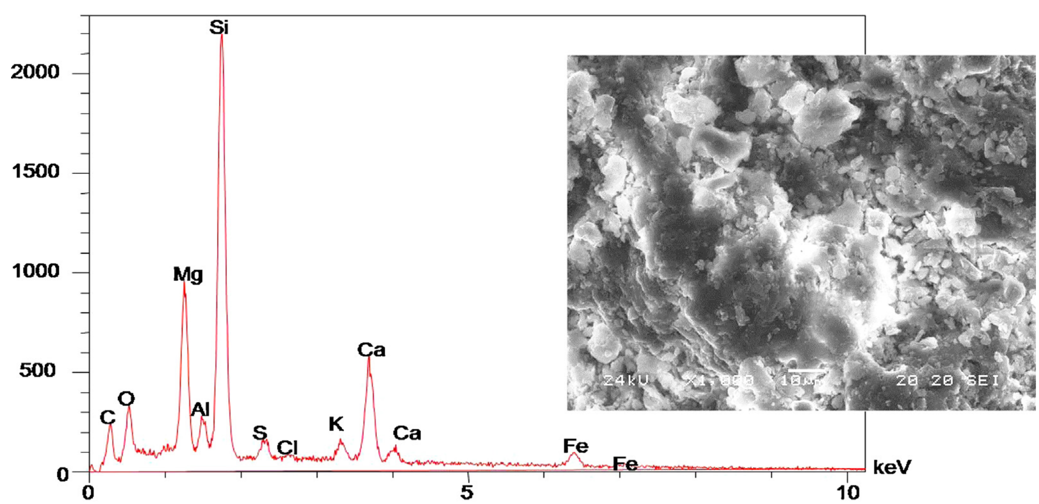
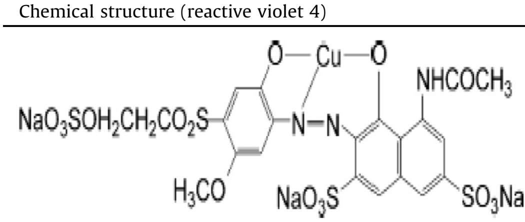


Fig. 2. Micrographs and elemental analysis of the basic raw clay (NC).

Table 1
Characteristics of the synthetic wastewater subjected to electrochemical treatment.

Chemical structure (reactive violet 4)	Parameters	Average value
	pH	6.8
	Conductivity (ms/cm)	1.5
	COD (mgO_2/L)	736
	BOD_5 (mg O_2/L)	137
	Chloride (mg Cl^-/L)	320
	Color (absorbance)	0.8
	UT-24 h (toxic unit)	10.76