Electrocoagulation/electroflotation of reactive, disperse and mixture dyes in an external-loop airlift reactor

Wafaa Balla [a,b], A.H. Essadki [a,*], B. Gourich [a], A. Dassaa [b], H. Chenik [a,b], M. Azzi [b]

[a] Ecole Supérieure de Technologie, Laboratoire Génie des Procédés et Environnement, B.P. 8012, Oasis, Casablanca, Morocco
[b] Faculté des sciences Aïn Chock, Laboratoire d'Electrochimie et chimie de l'environnement, B.P. 5366, Maarif, Casablanca, Morocco

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ABSTRACT

This paper studied the efficiency of electrocoagulation/electroflotation in removing colour from synthetic and real textile wastewater by using aluminium and iron electrodes in an external-loop airlift reactor of 20 L. The disperse dye is a mixture of Yellow terasil 4G, Red terasil 343 150% and Blue terasil 3R02, the reactive dye is a mixture of Red S3B 195, Yellow SPD, Blue BRFS. For disperse dye, the removal efficiency was better using aluminium electrodes, whereas, the iron electrodes showed more efficiency for removing colour for reactive dye and mixed synthetic dye. Both for disperse, reactive and mixed dye, 40 mA cm^{-2} and 20 min were respectively the optimal current density and electrolysis time. 7.5 was an optimal initial pH for both reactive and mixed synthetic dye and 6.2 was an optimal initial pH for disperse dye. The colour efficiency reached in general 90%. The results showed also that Red and Blue disappeared quickly comparatively to the Yellow component both for reactive and disperse dyes. The real textile wastewater was then used. Three effluents were also used: disperse, reactive and the mixture. The colour efficiency is between 70 and 90% and COD efficiency reached 78%. The specific electrical energy consumption per kg dye removed (E_{dye}) in optimal conditions for real effluent was calculated. 170 kWh/kg$_{dye}$ was required for a reactive dye, 120 kWh/kg$_{dye}$ for disperse and 50 kWh/kg$_{dye}$ for the mixture.

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1. Introduction

Textile industries use large amount of water and chemicals for finishing and dying processes. Dye wastewater usually consists of a number of contaminants including acids, bases, dissolved solids, toxic compounds, which are noticeable even at very low concentrations and need to be removed before the wastewater can be discharged.

Conventional methods for dealing with textile wastewater consist of various combinations of biological, physical and chemical methods [1,2]. Biological treatment of dying wastewater is cheaper than other methods, but it is less efficient for decolourization due to toxicity of the wastewater and the need for an aeration system. Although the coloured materials in wastewater can be effectively destroyed by advanced chemical oxidation such as UV/H$_2$O$_2$, O$_3$ [3,4] and adsorption using activated carbon [5,6], the costs of these methods are relatively high for an economically feasible treatment of the textile wastewater.

The electrocoagulation (EC) technique is considered to be potentially an effective tool for treatment of textile wastewaters with high removal efficiency. EC is a process consisting of creating metallic hydroxides flocs within the wastewater by electrodissolution of soluble anodes, usually made of iron or aluminium. Electrocoagulation has been applied successfully for treatment of potable water [7], food and protein wastes [8], textile wastewater [9,10], aqueous suspensions containing kaolinite, bentonite and ultrafine particles [11,12], fluoride containing water [13,14], restaurant wastewater [15,16], textile dyes solutions [17,18], and smelter wastewater containing harmful arsenic [19].

Although EC may be as cost-effective as chemical dosing [20,21], its main deficiency is the lack of dominant reactor design and modeling procedures. Mollah et al. [20] described six typical configurations for industrial EC cells and report their respective advantages and drawbacks. However, the literature reveals any systematic approach for these configurations for design and scale-up purpose. This situation stems mainly from the complex interactions between electrochemistry, colloidal forces and hydrodynamics that govern the behaviour of EC reactors.

The objective of this work is to demonstrate that airlift reactors can be suitable EC units. Airlift reactors constitute a particular class of bubble columns in which the difference in gas hold-up between two sections (namely, the riser and the downcomer) induces an overall liquid circulation without mechanical agitation [22,23]. They have been extensively applied in the process industry to carry out chemical and biochemical slow reactions, such as chemical oxi-

* Corresponding author. Tel.: +212 0 660878671.
E-mail address: essadki@est-uh2c.ac.ma (A.H. Essadki).

Table 1
Characteristics of the synthetic dyes.

Parameter						
Colour index	Yellow terasil 4G	Red terasil 343 150%	Blue terasil 3R02	Reactive Red S3B 195	Reactive Yellow SPD	Reactive Blue BRFS
Molar mass	1000–2000	1000–2000	1000–2000	1000–2000	1000–2000	1084
Percentage of pure dye	>90%	>90%	>90%	>90%	>90%	70%
pH value	8–9 (20 g/L water)	9 – 9.3 (20 g/L water)	6 – 7 (20 g/L water)	6.0–7.0 (100 g/L water)	6.0–7.0 (100 g/L water)	4.5–6.5
Fish toxicity	300 mg/L	200 mg/L	30 mg/L	>100 mg/L	>100 mg/L	26.8 mg/L
Λ_{max} (nm)	494	490	540	553	426	624
Water solubility at 293 K (g/L)	Disperse	Disperse	Disperse	>350 g/L	>400 g/L	>100 g/L
Thermal degradation (°C)	>200	>210	>200	>250	>250	>250

dation using O_2, Cl_2 or aerobic fermentation, but never as EC cells, as far as the authors know. Airlift reactors present two main designs: external-loop and internal-loop configurations. External-loop airlift reactors offer the advantage to allow various designs of the separator section, which favors gas disengagement at the top of the reactor and maximizes consequently the overall recirculation velocity at the expense of more complex reactor geometries. Their hydrodynamics has also been extensively studied in two-phase gas–liquid and three-phase gas–liquid–solid flows [24,25].

In previous work [26], a red dye from the Moroccan textile industry was used in a case study to validate this application of airlift reactors. Experimental results showed that the axial position of the electrodes and the residence time in the separator section were the key parameters to achieve good mixing conditions, to avoid bubbles/particles recirculation in the downcomer and to prevent flock break-up/erosion by hydrodynamic shear forces. Such optimum conditions corresponded to an optimum liquid overall recirculation velocity that was correlated to current, electrode position and dispersion height. Operation time and removal efficiencies were similar to those reported in conventional EC cells, but specific energy and electrode consumptions were even smaller without the need for mechanical agitation, pumping requirements and air injection, which could not be achieved in other kinds of conventional gas–liquid contacting devices.

Another study [27] concerning defluoridation was carried out using batch electrocoagulation/electroflotation (EC/EF) in two reactors for comparison purpose: a stirred tank reactor (STR) close to a conventional EC cell and an external-loop airlift reactor (ELAR). The respective influences of current density, initial concentration and initial pH on the efficiency of defluoridation were investigated. The same trends were observed in both reactors, but the efficiency was higher in the STR at the beginning of the electrolysis, whereas similar values were usually achieved after 15 min operation.

The objective of the present study is to investigate the decolourization of a reactive, disperse textile dye and their mixture in synthetic form and real effluent in aqueous solution using aluminium and iron electrode.

In this study, the aim is to demonstrate that such reactors can be used as an EC cell in which complete flotation can be achieved without air injection and good mixing conditions can be obtained without mechanical agitation. This means that pollutants should be floated to the surface only by tiny bubbles of hydrogen and oxygen gases generated from water electrolysis; similarly, the overall liquid circulation responsible for mixing in airlift reactors should result only from electrochemically generated bubbles. In this way, the removal of a textile dye used in a Moroccan factory by electrocoagulation/electroflotation (EC/EF) has been investigated.

2. Materials and methods

2.1. Materials

Three synthetic wastewaters were prepared from different dyes textile using drinking water:

- The first synthetic wastewaters containing 3 reactive dyes: Yellow SPD, Red S3B 195, Blue BRFS
- The second synthetic wastewaters containing 3 disperse dyes: Yellow Terasil 4G, Red disperse 343 150% and Blue Terasil 3R02.
- The third one was the mixture of the first and the second synthetic wastewaters, containing hence reactive and disperse dyes.

These synthetic wastewaters were experimentally investigated, in order to determine the suitable operating conditions to treat the real reactive, disperse wastewaters and their mixture.

The concentration of the solution is 400 mg/L. The prepared masses of each dye are made by respecting their weight ratio in the tissue as suggested by the industrialists. Thus, the mass percentages of each type of dye contained in a tissue are the following: the mixture of the three dispersive dyes: 0.188% for the Terasil Yellow, 0.412% for the Terasil Red and 0.9% for Terasil Blue. The mixture of the three reactive dyes: 0.336% for Yellow SPD, 0.92% for Red S3B and 0.8% for Blue BRFS. These percentages are transposed in mass percentages in a solution of 400 mg/L. The characteristics of the dyes are summarized in Table 1.Three real wastewaters have been collected: one from the ducts of acid dyestuff containing reactive dyes, the second one collected in ducts of basic dyestuff containing dispersive dyes, the third one was obtained from a tank containing a mixture of acid and basic dyestuff. The dyes used in the experiments and the real wastewaters were provided from *ITEX*, Textile industry (Casablanca, Morroco). The characteristic of the real wastewaters is shown in Table 2.

The details of the reactor design are illustrated are presented in Fig. 1 and discussed in a previous work [26]. All the experiments were conducted at room temperature (20 ± 1 °C) and atmospheric pressure in the semi-batch mode (reactor open to the gas, closed to the liquid phase). Contrary to conventional operation in airlift reactors, no gas phase was sparged at the bottom in the riser. Only electrolytic gases induced the overall gas recirculation resulting from the density difference between the fluids in the riser and the downcomer. Two readily available aluminium or iron flat electrodes of rectangular shape (250 mm × 70 mm × 1 mm) were used as the anode and the cathode, which corresponds to $S = 175$ cm² electrode surface area. The distance between electrodes was e = 20 mm, which is a typical value in EC cells (see, e.g., [20]). They were treated with HCl aqueous solution for cleaning prior use to avoid passivation. The electrodes were placed in the riser, parallel to the main flow direction to minimize pressure drop in the riser and maximize the recirculation velocity. The axial position of the electrode could also be varied in the column. The distance (H_1) between the bottom of the electrodes and the bottom of the riser

Table 2
Characteristics of real dyes effluent.

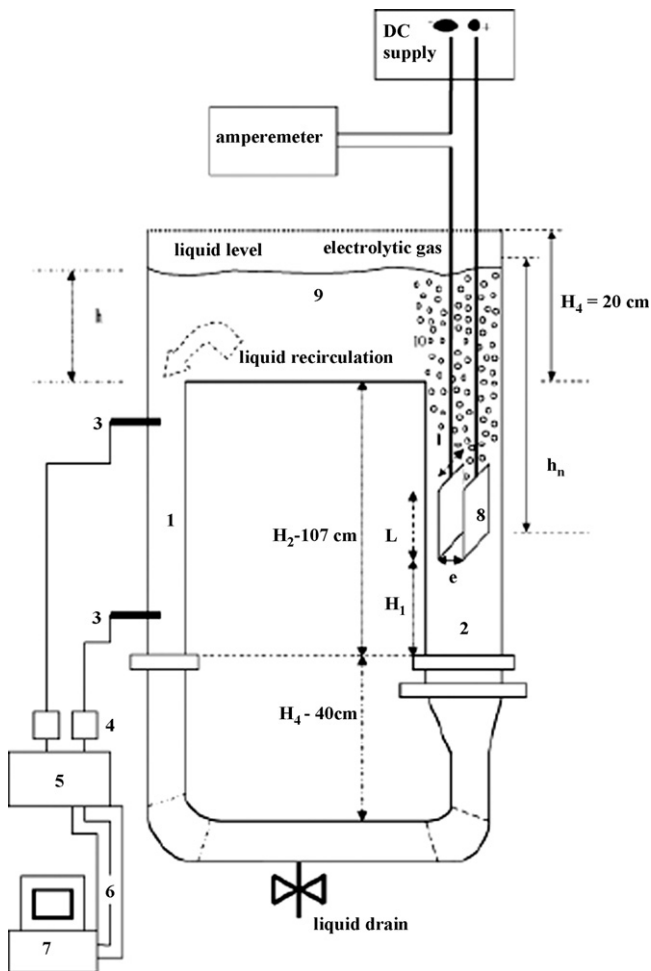|	Disperse	Reactive	Mixture
pH	4.9	10.7	6.8
Conductivity (mS/cm)	0.615	28.5	4.65
COD (mg/L)	890	3570	920

Fig. 1. Externeal-loop airlift reactor (1: downcorner section; 2: riser section 3: conductivity probes; 4: conductimeter, 5: along output/input terminal panel (UEI-AC-1585-1); 6: 50-way ribbon cable kit; 7: data acquisition system; 8: electrodes; 9: separator; 10: electrochemically generated bubbles).

is $H_1 = 47$ cm. EC was conducted in the intensiostat mode, using a digital DC power supply BK1794 (0–32 V/0–30 A) and recording potential during the experiments. Current ($I = j \cdot S$) was varied between 5 and 9 A.

2.2. Methods

Dye concentration was estimated from its absorbance characteristics in the UV–vis range (200–800 nm), using the wavelength that provided the maximum intensity ($\lambda_{max} = 436$, 525 and 620 nm) by UV–vis spectrophotometer (Pye Unicam, SP 8–400, UK). COD was measured using the standard closed reflux colorimetric method. The pH was measured with a pH meter (PHM 220 Radiometer analytical). Conductivity was determined by a conductivity meter (CDM 210 Radiometer analytical).

The conductivity was adjusted using the addition of sodium chloride. It was varied between 1 and 29 mS/cm which covers the range usually explored in the literature [28]. NaCl is a salt exhibiting low toxicity at moderate level, reasonable cost, high conductivity and high solubility, but it plays also the role of supporting electrolyte. This addition had always a negligible effect on the influent pH of the solutions.

During EC process, absorbance was measured over time on samples recovered from the reactor. To cover the absorbance of various types constituting the mixture, 3 wavelengths were used: 436, 525 and 620 nm. Absorbance was measured every 5 min in order

to determine the time required for the establishment of suitable efficiency.

Colour efficiency is expressed as $Y_{COL}((A_0 - A)/A_0)$ and COD removal efficiencies as $Y_{COD} ((COD_0 - COD)/COD_0)$.

A_0 and A are respectively the initial absorbance and the absorbance at a certain time.

$(COD)_0$ and COD are respectively the initial COD and the COD at a certain time expressed in kg/L.

The specific electrical energy consumption per kg dye removed (E_{dye}) was calculated as follows:

$$E_{dye} \ \ (kWh/kg \, dye) = \frac{UI \cdot t}{1000 \cdot V \cdot (C_0 Y_{COL})} \tag{1}$$

using initial dye concentration C_0 (kg/m^3), current intensity I (A), cell voltage U (V), electrolysis time t (s), liquid volume V (m^3).

3. Results and discussion

Decolourization efficiency, COD abatement were investigated in terms of initial pH, current density, and electrolysis time in order to determine the optimum operating conditions for maximum decolourization efficiency of the reactive, disperse dyes and their mixture.

3.1. Treatment of disperse synthetic wastewater: using Al electrodes

For disperse synthetic wastewater, preliminary experiments showed that only the aluminium electrodes have an important efficiency compared to the iron electrodes that present low values of efficiency. These results were confirmed by Phalakornkule et al. [29].

3.1.1. Effect of current density on the colour removal efficiency

In all electrochemical processes, current density is the most important parameter for controlling the reaction rate within the electrochemical reactor [30]. It is well known that current density determines the production rate of coagulant, adjusts also bubble production, and hence affects the growth of flocs [20,31]. To investigate the effect of current density j on the efficiency of colour removal, electrocoagulation process was carried out using various current densities at fixed initial concentration $C_0 = 400$ mg/L with pH 6.2.

Fig. 2 shows the evolution of the colour efficiency with time at different current densities; 620 nm was used as a wavelength. It can be observed that 100% was reached after 20 min for a current density of 28.6 mA cm^{-2}. 15 min are sufficient to reach 100% for a current density greater than 40 mA cm^{-2}. The same tendency was observed by using 436 and 525 nm as wavelength for absorbance measurement.
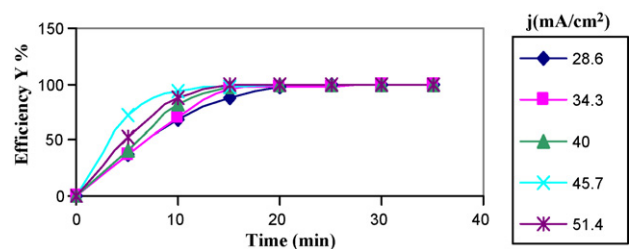

Fig. 2. Effect of current density on the decolourization efficiency: Co: 400 mg/L, initial pH: 6.2, conductivity: 3.2 mS/cm, synthetic disperse dye), $\lambda_{max} = 620$ nm.
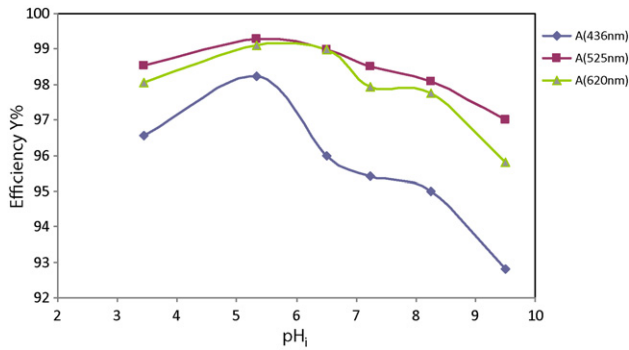
Fig. 3. Effect of initial pH on decolourization efficiency by EC, electrolysis time: 20 min, conductivity = 3.2 mS/cm, j = 45.7 mA/cm^2, synthetic disperse dye).

Fig. 4. Effect of current density on the decolourization efficiency: Co: 400 mg/L, initial pH: 6.2, conductivity: 3.2 mS/cm, synthetic reactive dye), λ_{max} = 620 nm.

3.1.2. Effect of influent pH on the colour removal efficiency

Fig. 3 shows the influence of initial pH on the removal efficiency by EC. For all wavelengths used the maximum efficiency was obtained for an initial pH of about 5.3, but it is clear that the efficiency used for a wavelength of 436 nm is lower than that when one uses both other wavelengths. This can be explained by the fact that the kinetics of decolourization is not the same for each component of the dye.

Two main mechanisms are generally considered to explain pollution removal: *precipitation* for pH lower than 4 and *adsorption* for higher pH. Adsorption may proceed on Al(OH)$_3$ or on the monomeric Al(OH)$^{4-}$ anion, depending on the dye chemical structure. The formation of Al(OH)$_3$(s) is therefore optimal in the 4–9 pH range. However, pH affects also bubble size [32]. Typical bubble sizes in electrocoagulation always fall in the range of 20–70 μm [33]. They are far smaller than those observed in conventional air-assisted flotation, which provides both sufficient surface area for gas–liquid–solid interfaces and mixing efficiency to allow the aggregation of tiny destabilized particles. Hydrogen bubbles, which usually obey to a lognormal size distribution, are also known to be the smallest about neutral pH [34].

As a conclusion, pH adjustment is compulsory before EC in airlift reactors, as in conventional pH may be adjusted in the optimum range in order to achieve a compromise between best coagulation and best flotation. The optimum range may however vary as a function of electrode material and dye structure. In the following sections, initial pH will be fixed at about 6.2 to maximize COD removal efficiency.

3.2. Treatment of reactive synthetic wastewater: using iron electrodes

In the case of reactive synthetic wastewater, preliminary experiments showed that only the iron electrodes have an important efficiency compared to the aluminium electrodes that present low values of efficiency.

3.3. Effect of current density on the colour removal efficiency

Fig. 4 shows that the removal efficiency reached 100% at times between 30 and 40 min when current density increases between 28.5 and 51.4 mA cm^{-2}. Minimum 45.7 mA cm^{-2} current density and 20 min of electrolysis time are required for good decolourization efficiency (>80%). The absorbance was measured at 620 nm as wavelength. The same tendency of the results was observed for wavelengths of 436 and 525 nm.

It should be noted that negative values of the efficiency for the ten first minutes correspond to a greenish colouring which appeared during the first moments of electrolysis.
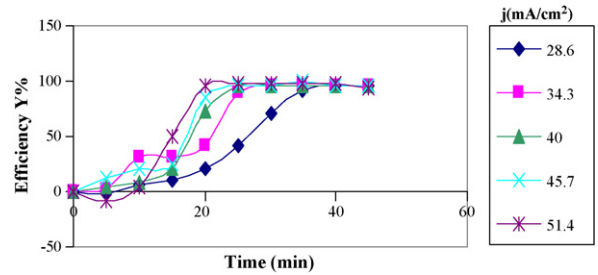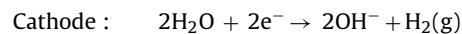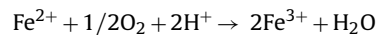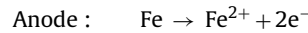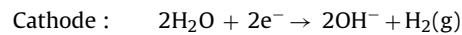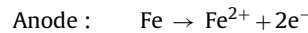
Two mechanisms are possible during EC by using iron as sacrificial anode:

Mechanism I:

$$\text{Anode}: \quad Fe \rightarrow Fe^{2+} + 2e^-$$

$$Fe^{2+} + 1/2O_2 + 2H^+ \rightarrow 2Fe^{3+} + H_2O$$

$$\text{Cathode}: \quad 2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$$

$$\text{So}: \quad Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3(s)$$

Mechanism II:

$$\text{Anode}: \quad Fe \rightarrow Fe^{2+} + 2e^-$$

$$\text{Cathode}: \quad 2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$$

$$\text{So}: \quad Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2(s)$$

The green colour corresponds to the formation of the Fe(OH)$_2$ (mechanism II). Fe(OH)$_2$ is then oxidized to allow the formation of Fe(OH)$_3$.

3.3.1. Effect of influent pH on the colour removal efficiency

The kinetics of Fe^{2+} conversion to Fe^{3+}, are strongly affected by the pH; the surface charge of the coagulating particle also varies with pH [35]. In general, as shown in Fig. 5 [36], at lower and higher pH, Fe is increasingly soluble. Note that, in this case, the solid line represents the solubility equilibrium of Fe(OH)$_3$ and the dotted line represents the predominance limits among soluble chemical species. To examine its effect, the sample was adjusted to a desired pH for each experiment by using sodium hydroxide or hydrochloric acid solutions.

Fig. 6 shows the removal efficiency of reactive dye as a function of the initial pH.

For all wavelengths used the maximum efficiency was obtained for an initial pH of about 7.
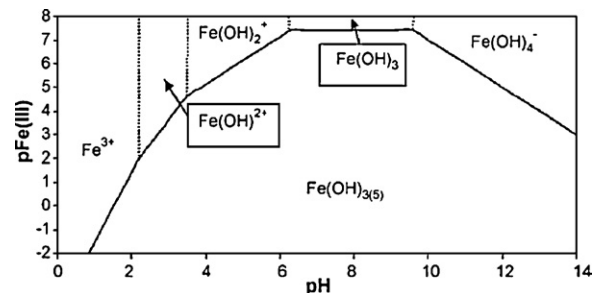

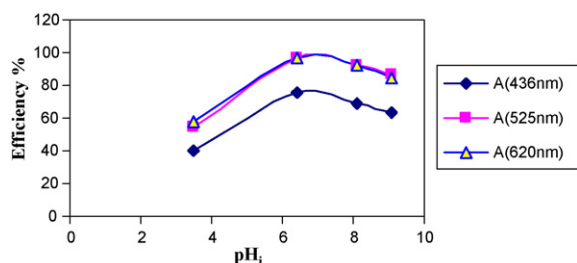**Fig. 5.** Predominance-zone diagrams for Fe(III) chemical species in aqueous solution.

Fig. 6. Effect of initial pH on the decolourization efficiency, electrolysis time: 20 min, conductivity = 3.2 mS/cm, $j = 45.7$ mA/cm^2, synthetic reactive dye).

Current density and electrolysis duration were fixed respectively to 45.7 mA cm^{-2} and 20 min. As shown in Fig. 5 [36], at lower pH, Fe(OH)$^{2+}$ were produced which are disadvantageous for colorant precipitation [30].

It is also observed that the efficiency used for a wavelength of 436 nm is lower than that when one uses both other wavelengths. This confirms that the kinetics of decolourization differs according to the component.

In summary, higher colour removal efficiency was obtained in neutral media, as reported by several authors [37].

The mechanism of the electrochemical process in aqueous systems is quite complex. However, the colour removal process may involve the dye molecule adsorbing by both electrostatic attraction and physical entrapment. The insoluble metal hydroxides of iron can remove dye molecules by surface complexation or electrostatic attraction. In surface complexation, it is assumed that the dye molecule can act as a ligand to bind a hydrous iron moiety with precipitation and adsorption mechanisms [30,38]:

Also, the dye actually may be complexing with the iron hydroxide forming ionic bonds [38]:

$$R\text{–}SO_3Na + (OH)_3(H2O)Fe \rightarrow R\text{–}SO_3\text{–}OH)_2H_2OFe + Na^+ + OH^-$$
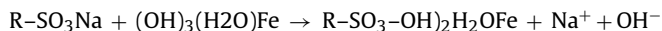
According to the reactions presented above, pH of the medium have to increase during the process. This fact is shown in Fig. 7.

3.4. Treatment of mixture synthetic wastewater: using electrodes of Fe

The same operating conditions using iron electrodes to treat reactive dye were used to treat this wastewater.

3.4.1. Effect of current density on the colour removal efficiency

Fig. 8 shows the decolourization efficiency as a function of current density and of time. As the applied current density was increased from 28.6 to 51.4 mA cm^{-2}, the asymptotic value of decolourization efficiency was reached quickly. Negative values of the removal indicate the green colour appeared during a certain time of the electrolysis. This time persists longer if the density of current is relatively low.
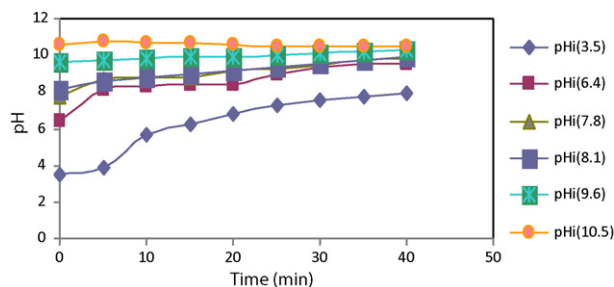

Fig. 7. The variation of pH during the electrocoagulation process conductivity = 3.2 mS/cm, $j = 45$ mA/cm^2, synthetic reactive dye).
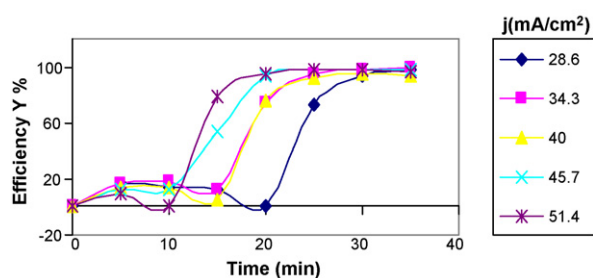

Fig. 8. Effect of current density on the decolourization efficiency, $\lambda_{max} = 620$ nm (synthetic mixture dyes).

Minimum 45.7 mA cm^{-2} and 20 min are required for good decolourization efficiency (>80%).

3.4.2. Effect of initial pH on the efficiency of colour removal

To examine the effect of pH, the dye solution was adjusted to the desired pH for each experiment by adding sodium hydroxide or sulfuric acid solution. The colour removal for dye solutions with various initial pH values was shown in Fig. 9. The results revealed that when pH of the dye solutions was between 7.5 and 8, there was maximum colour removal efficiency. Current density and electrolysis duration were fixed respectively to 40 mA cm^{-2} and 20 min.

Weak values of the removal efficiency were also observed when 436 nm is used for the absorbance measurement. According to the above results we can conclude that:

For disperse dye, Bleu terasil and Red terasil disperse disappeared quickly compared to Yellow terasil. For reactive dye, Bleu SPD and Red 195 disappeared quickly compared to Yellow BRF.

3.5. Treatment of real wastewater

Experiments performed by synthetic wastewater allowed to determining optimum parameters used to treat real wastewater. COD and colour removal efficiencies were followed.

3.5.1. Reactive wastewater

Experiments were carried out using 20 L of real reactive wastewater consisting of three textile dyes. The current density, pH, conductivity were adjusted respectively to 40 mA cm^{-2}, 7.5.

According to Fig. 10, 40 min of operating time is sufficient for decolourization efficiency of about 76%, and the optimum electrolysis time showed in Fig. 11 was 45 min for the COD

3.5.2. Disperse wastewater

Experiments were carried out using 20 L of real disperse wastewater, the current density, pH, conductivity were adjusted respectively to 40 mA cm^{-2}, 6.2.
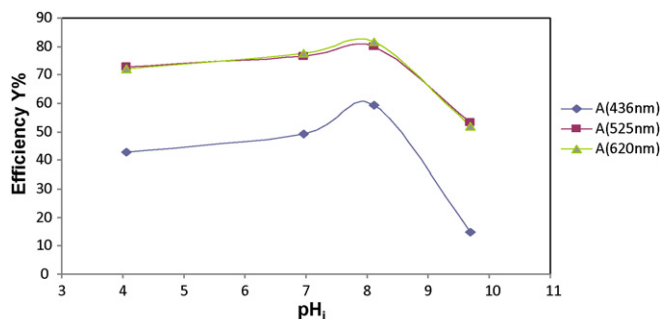

Fig. 9. Effect of initial pH on the decolourization efficiency, electrolysis time = 20 min (synthetic mixture dyes).
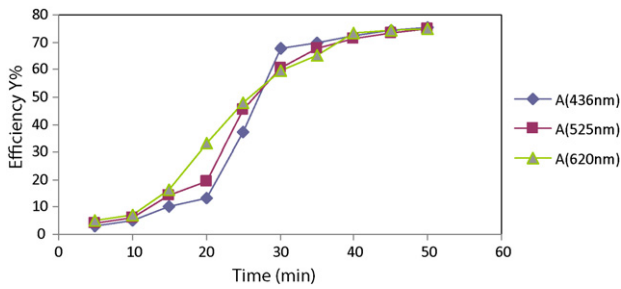
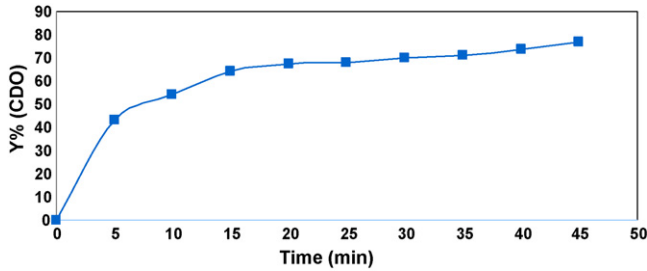**Fig. 10.** Evolution of the decolourization efficiency according to time (real effluent disperse dye).

Fig. 11. Evolution of the COD abatement according to the time (real effluent disperse dye).
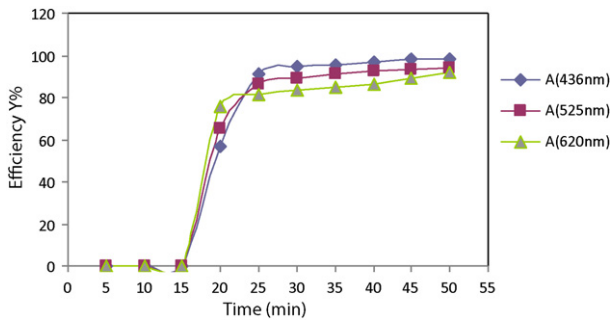

Fig. 12. Evolution of the decolourization efficiency according to time (real effluent reactive dye).

According to the results showed in Fig. 12, the optimum electrolysis time was 25 min for the colour removal from both dye solutions corresponding to 98%, however the optimum electrolysis time showed in Fig. 13 was 45 min for the COD abatement.

3.5.3. Mixture of real wastewater

Experiments were carried out using 20 L of real mixture wastewater with an initial pH 7.6 and a current density of 40 mA cm^{-2}. The evolution of the decolourization efficiency and the COD abatement are reported in Fig. 14.
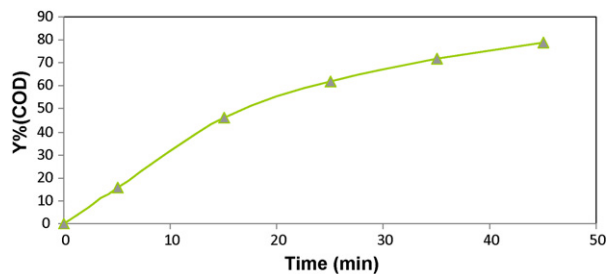

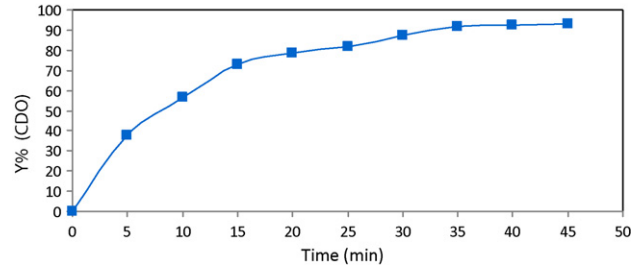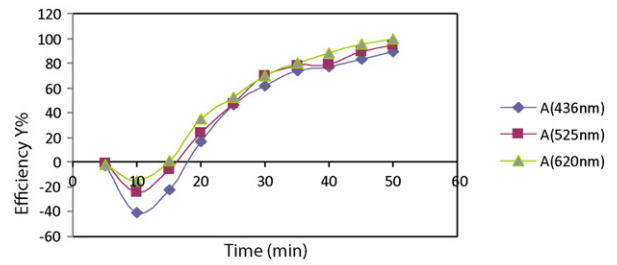**Fig. 13.** Evolution of the COD abatement according to time (real effluent reactive dye).

Fig. 14. Evolution of the decolourization efficiency and the COD abatement (real effluent: mixture dyes).
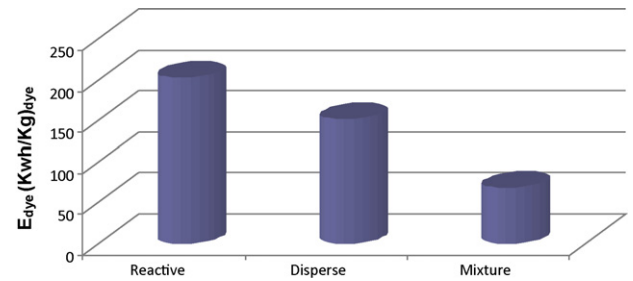

Fig. 15. specific electrical energy consumption per kg dye removed (E_{dye}) in optimal conditions for real effluent: reactive, disperse and mixture dyes.

The results show that the required electrolysis time for both colour removal and COD abatement was 45 min corresponding of both cases to an efficiency over 90%.

Fig. 15 shows the specific electrical energy consumption per kg dye removed (E_{dye}) in optimal conditions for each case to reach 80% as colour efficiency. It is shown that the reactive dye required more energy followed by disperse and mixture. According to Table 2, COD and conductivity are not the same for the three types of dyes. For reactive dye, although the conductivity is higher the COD has a high value (3570 mg/L) comparatively to disperse and mixture dyes. Disperse and mixture dyes have almost the same COD. The conductivity of mixture dye is however higher (4.65 mS/cm for mixture and 0.615 mS/cm) leading to a decrease of the specific energy since for a fixed current intensity the increase of conductivity allows to a decrease in voltage.

4. Conclusion

In this study, EC was confirmed as a good process to remove a mixture of dyes. Iron anodes were more adequate for reactive and mixture (disperse + reactive) dyes, whereas the aluminium electrodes were more efficient for disperse dyes removal. The EC of synthetic wastewater confirmed that the removal kinetic is not the same for each component constituting the dye.

A total flotation of the flock was obtained by using an external-loop airlift reactor. The pollutants were floated to the surface only by tiny bubbles of hydrogen gases generated from water electrolysis; similarly, the overall liquid circulation responsible for mixing in

airlift reactors should result only from electrochemically generated bubbles.

The airlift reactor can be used for a continuous process and that the treated water will be recovered without needing to use of filtration.

For reactive and mixture dyes, optimal initial pH was of about 7.5. 45 min of electrolysis time and 40 mA cm^{-2} as a current density were sufficient to reach almost 80% of decolourization efficient and COD abatement for reactive dye.

For the mixture of real wastewater COD reached 90% and decolourization efficiency reached 98% when the electrolysis duration was 45 min and when the current density used was 40 mA cm^{-2}.

For disperse dye, optimal initial pH was of about 6.2. The use of 40 mA cm^{-2} as a current density and 45 min as a duration time of electrolysis were sufficient to obtain almost 100% of decolourization efficiency and 80% of COD abatement.

To reach 80% as a decolourization efficiency, 170 kWh/kg$_{dye}$ was required for a reactive dye, 120 kWh/kg$_{dye}$ for disperse and 50 kWh/kg$_{dye}$ for the mixture. The specific energy required depends on the initial COD and conductivity.

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