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Elimination of two cationic dyes by electro coagulation in single and binary system: parametric study

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Abstract - *In this work, the removal of two cationic dyes {greenmethyl and basicyellow 28} by electro coagulation using aluminium as anode and stainless steel as cathode was studied. First, the effect of the most important parameters {current intensity, initial pH of and initial concentration} on decolorization in single system was investigated. The results showed that the pollutants are totally removed (with efficiently of 100 %) and the adsorption kinetics was directly related of the pollutant nature and the operating conditions such as (Initial pH, concentration and contact time). Secondly, the removal of the dyes in a binary system was studied. Results showed that adding BY28 affects positively the removal of GM by increasing the removal of the BY 28, which can be explained by synergic effect of decolorization.*

Résumé - *Dans ce travail, nous avons étudié le procédé d'électro coagulation en système simple et binaire de deux colorants cationiques {vert de méthyle et jaune basique 28} en utilisant l'aluminium comme anode et l'acier inoxydable comme cathode. Dans la première partie, nous avons étudié l'effet de trois paramètres à savoir: intensité de courant, le pH initial et la concentration en colorant, sur la décoloration de ces polluants dans le système simple. Les résultats obtenus ont montré de façon claire que le rendement de décoloration des deux colorants en système simple, a atteint le pourcentage de 100 % et que les cinétiques de disparition varient selon la nature de colorant étudié. Dans une seconde partie, nous nous sommes intéressés à l'étude de l'élimination de ces deux colorants dans un mélange binaire. Les résultats ont montré que l'ajout de BY28 a un effet positif sur l'élimination de GM en augmentant l'élimination de BY 28, ce qui peut être expliqué par effet synergique de décoloration*.

Keywords: Electro coagulation - Green-methyl - Basic yellow28 - Single and binary system.

1. INTRODUCTION

The pollution of environment byorganic contaminants originating from urban and industrial is a major challenge for scientific public communities. The presence of dyes in industrial effluents such as textile wastewaters may constitute a severe threat for the environment (Kobya *et al.* 2003). A treatment of such a wastewater is required in order to comply with environmental recommendations (Holt *et al.* 2005). Many treatment methods were proposed and used such as physico chemical methods, chemical oxidation, and adsorption (Zermane *et al.* 2013).

Recently, many researches had proved the efficiency of electrochemical methods in the treatment of wastewaters containing organic pollutants (Khelifa *et al.* 2009). Among these methods, electro coagulation (EC) was tested as an efficient process to remove several pollutants such as heavy metals, colloids, fluoride, emulsions (Chen *et al.* 2003).

In EC, coagulant is generated *in situ* in the solution, by means if dissolution of soluble anode. Aluminium and iron are currently used such as anode material. The produced coagulant currently performs better than chemical coagulant (Holt *et al.* 2002). Coagulants produced by EC are able to destabilize suspensions, adsorb dissolved pollutants such as heavy metal ions and dye molecules (Kobya *et al.* 2003).

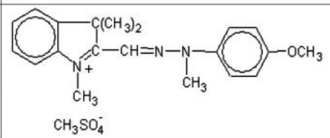
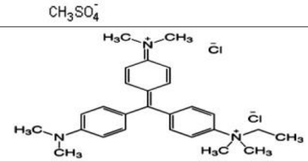
The aim of this work is to study main parameters influencing the removal by EC of two dyes; Green Methyl (GM) and Basic Yellow 28 (BY28) in single and binary systems. The studied parameters are current intensity, initial pH and initial concentration.

2. MATERIAL AND METHODS

2.1 Organic pollutants

In our study, two basic dyes were chosen as organic pollutants; green methyl and basic yellow 28. The main characteristics of both dyes are given by **Table 1**.

Table 1: Properties of studied dyes

Dye	Molecular structure	λ_{max} (nm)	Molar mass ($g.mol^{-1}$)
Basic Yellow 28		460	433
Green Methyl		632	472

2.2 Experimental setup

Electro coagulation reactor comprises a glass beaker of 1 liter volume with magnetic stirrer, a power supply (30V, 10A), and an ammeter. The electrodes were made of sheets of Aluminum (99.5 % Al)as anode and stainless steel as cathode. Each electrode was of 32 cm^2 of surface area and they were distant of 1.5 cm each other.

Fig. 1: Photography experimental setup

2.3 Experimental procedure

The conductivity of studied solutions was adjusted by adding 1 g of sodium chloride. All the studied solutions were obtained by dilutions from stock solutions at 1000 mg/l. The pH of the solution was adjusted by adding appropriate amounts of NaOH or H_2SO_4.

Before every run, anodes of aluminum were cleaned by 2N NaOH solution. After each cleaning, aluminium anodes were weighted before put in the reactor. Samples were periodically withdrawn from reactor and the filtered with silicone filter of 2 µm.

2.4 Analytical methods

The pH was measured by a MV 870 digital -pH- MESSGERAT. The determination of dyes concentration was achieved by a SHIMATZU spectrophotometer in the appropriate λ_{max}.

Using the spectrophotometer, the absorbance between 400 and 800 nm was measured. Based on absorption maxima for each dye, calibration curves were established in order to estimate its concentration. The maximum absorbance for the studied dyes are λ_{max} (GM) = 632.5 nm and λ_{max} (BY28) = 460 nm.

In the case of binary mixture of (GM, BY28), the residual (figure 2) concentrations are corrected as follows (Cheknane *et al.* 2010):

$$C_{BY28} = \frac{\varepsilon_{GM2}\, d_1 - \varepsilon_{GM1}\, d_2}{\varepsilon_{BY,1}\,\varepsilon_{GM2} - \varepsilon_{BY,2}\,\varepsilon_{GM1}} \qquad (1)$$

$$C_{BY28} = \frac{\varepsilon_{BY2}\, d_{12} - \varepsilon_{BY1}\, d_1}{\varepsilon_{BY,1}\,\varepsilon_{GM2} - \varepsilon_{BY,2}\,\varepsilon_{GM1}} \qquad (2)$$

where (ε_{GM1}, ε_{BY1}) and (ε_{GM2}, ε_{BY2}) are respectively absorptivity constants of BY28 and GM.

The values of absorptivity constants are given in the **Table 2**.

Table 2: Absorptivity constants ε for used dyes

Dye	λ_{max}, 460 nm	λ_{max},632.5 nm
BasicYellow 28	0.0433	0.0004
Green Methyl	0.0014	0.0575

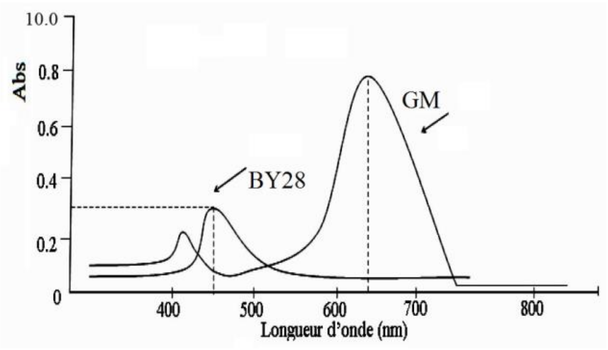


Fig. 2: Visible absorption spectra for used dyes

3. RESULTS AND DISCUSSION

3.1 Effect of current intensity

Current intensity is considered as key parameter in electro coagulation process (Drouiche *et al.* 2011). It has been established that current intensity plays a crucial role in abetment kinetics and reaction rate. [4]. In this study, a series of current intensities ware used: 100 mA, 200 mA, 600 mA, 800 mA and 1000 mA.

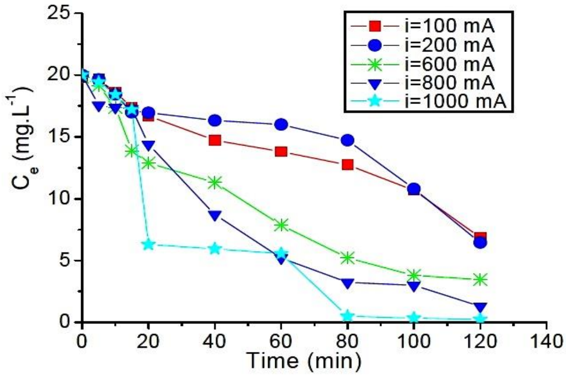


Fig. 3: Effect of current intensity on the removal of GM
{[GM]$_{0;}$ 20mg/l; initial pH 6; [NaCl] ; 1g/l}

The obtained results are illustrated in figure 3. It can be observed that for the applied currents of 100 mA and 200 mA the removal rate is lower, while for the remaining current intensity values (600 mA, 800 mA and 1000 mA), the removal of GM is more important and the kinetics is faster.

The quantity of coagulant responsible of the elimination of GM is related to the current intensity according Faraday law which improves the adsorption of dye molecules.

3.2 Evolution of pH with current intensity

Figure 4 shows the evolution of pH in the solution of 20 mg/l initial GM concentration and initial pH of 6. The obtained results indicate a clear increase in pH values during the electro coagulation process followed by a plateau.

The pH attains the value of 8 after 100 min treatment for current intensities 100 mA and 200 mA and pH 10 for I = 600 mA and I = 800 mA and a pH of 11 for I = 1000 mA. In conclusion, the higher is current intensity, the higher is the final pH.

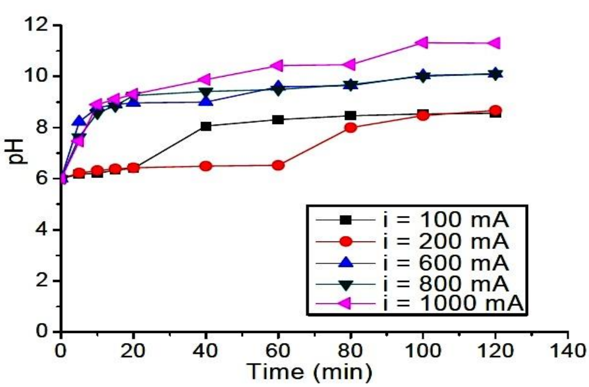


Fig 4: Variation of pH in function of time for different current intensities
{ [GM]$_0$; 20 mg/l; initial pH, 6; [NaCl] ; 1g/l}

3.3 Effect of initial pH

In order to investigate the effect of initial pH on the removal kinetics of the studied dyes, GM and BY28, three values of initial pH were chosen: 3, 6 and 9. The results are given in figure 5.

From this figure, it may be observed that the initial has an important effect on the removal kinetics. In fact, the electro coagulation is more significant at pH (9), with a faster removal rate compared with other initial pH values. The treatment efficiency is in the following order: pH_0 (3) < pH_0 (6) < pH_0 (9).

According to Mameri *et al*. (1998), electro coagulation process strongly depends on solution pH because it is affected by aluminum speciation which has an effect on decolonization mechanism.

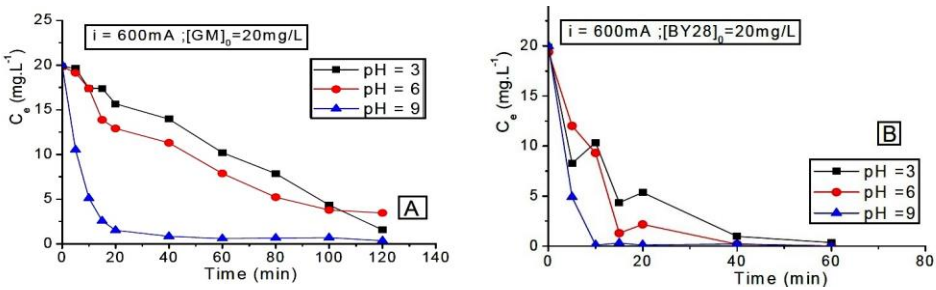


Fig. 5: Effect of initial pH on decolorization efficiency of: **A**): GM, **B**): BY28

3.4 Effect of initial concentration

Initial concentration of the studied dyes was varied from 5 to 20 mg/l. The effect of initial concentration on dyes removal is presented in figure 6.The different initial concentrations in dyes result in similar kinetics trends.

The abetment kinetics as much important as the initial concentration is slow. The treatment of concentrated solutions requires more reaction time to reach low concentrations. It can be concluded that the lower is the initial concentration the betters the color removal efficiency.

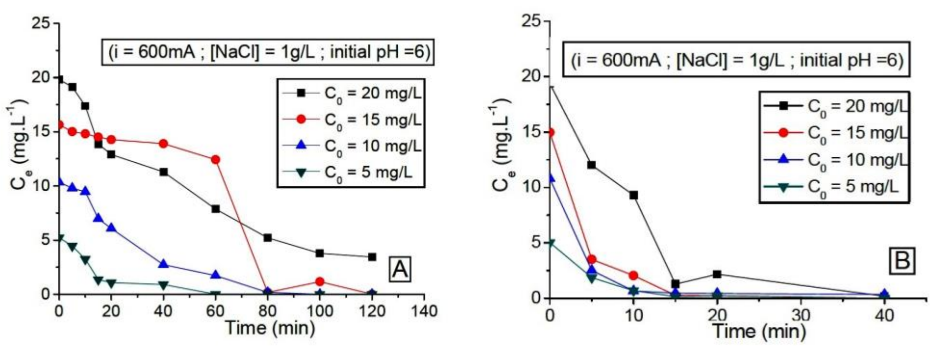


Fig. 6: Effect of initial concentration on decolorization efficiency of:
A) GM, **B**) BY28

3.5 Elimination of GM and BY28 in a binary mixture

In practice, there are many situations where effluents contain simultaneously the two dyes such as (GM, BY28).Thus, the study of the effect of the presence of one dye on the other dye is studied. This mainly demonstrates that the coagulant generated by electro coagulation using aluminum anode is able to simultaneously remove both dyes.

From results of figure 7, it may be observed that for all studied ratios (r=GM/BY28),the kinetics is similar to behavior in single system. Furthermore, it is obvious that adding BY28 affects positively the removal of GM by increasing the removal of the later. This may be explained by a phenomenon of competitive adsorption by synergic effect.

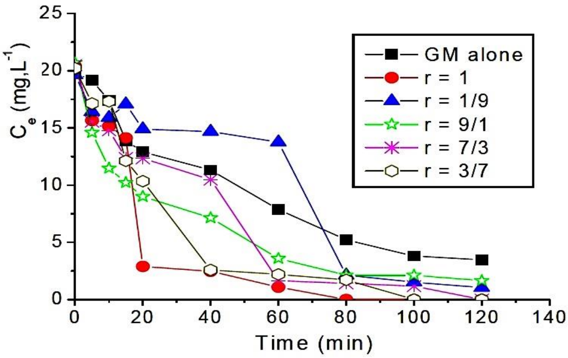


Fig. 7: Effect of the presence of YB28 on the removal of MG. { I, 600mA; initial pH, 6; $[GM]_0$= 20mg/l}

4. CONCLUSION

Removal of two dyes (GM and BY28) by electro coagulation using aluminium anode was studied in single and binary systems. These conclusions may be withdrawn:

-Increasing current intensity from 100 mA to 1000 mA, for both studied dyes, leads to better removal efficiencies. However, a value of 600 mA seems to be optimal for economic considerations.

- The best initial pH is pH = 9 for both dyes.
- Low dye concentrations are better removed by electro coagulation.
- The study of the removal of binary mixture shows that the dyes may be removed simultaneously by electro coagulation. Obtained results show that the presence of one dye may strongly affect the removal of the other which suggests occurrence of competition either by synergetic or antagonistic effect.

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Conflict of interest- The authors declare that they have no conflict of interest.

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