Chemical Methodologies 7(2023) 183-199

Chemical Methodologies

Journal homepage: http://chemmethod.com

Original Research Article

Experimental Study and Modeling by the Complete Factorial Plan of the Elimination of Textile Dye by Electrocoagulation Using Aluminum from Recycled Cans

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ARTICLE INFO

Article history

Submitted: 2022-09-09
Revised: 2022-10-23
Accepted: 2022-12-06
Manuscript ID: CHEMM-2211-1624
Checked for Plagiarism: Yes
Language Editor:
Dr. Fatimah Ramezani
Editor who approved publication:
Dr. Sami Sajjadifar

DOI:10.22034/CHEMM.2023.369066.1624

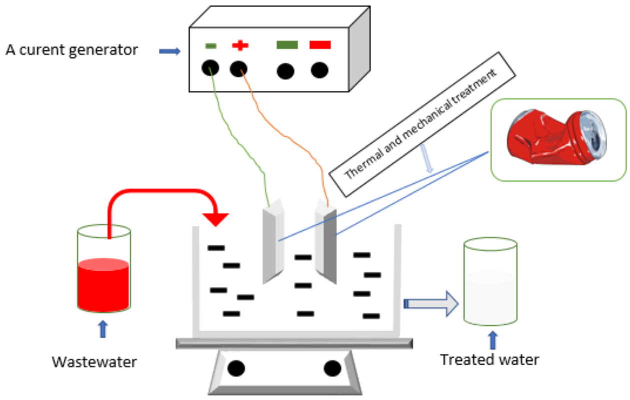
KEYWORDS

Electrocoagulation, recycled aluminum
Non-recycled aluminum
Complete factorial plan

ABSTRACT

This study aims to apply the electrocoagulation (EC) process to eliminate a textile dye, in the case of Azucryl red (AR) using aluminum electrodes from recycled cans to obtain a perfect and economic elimination of the dye. The parameters followed in this electrocoagulation study are the initial pH, the distance between the electrodes, the intensity of the current, the salinity, and the initial concentration of the dye. We tested the effects of two types of electrodes: Aluminum in cans (recycled) and non-recycled aluminum. The results obtained for recycled aluminum electrodes made it possible to get discoloration rates of up to 99,76%, for an initial pH equal to 8 in a distance of 1 cm, an electrolysis time corresponding to 35 minutes, an imposed current of 0,25 A, a quantity of NaCl of 1 g/L, and 94,16% for non-recycled aluminum at t = 60 min. Modelization by the plan of experiments was carried out, and the models obtained by the complete factorial plan represent the experimental results well. According to the costs of treatment by electrocoagulation, we can consider that for intensity of 0,25 A (optimal intensity), the cost of treatment is 3,52.10-3 DZD (2,4.10-5 $) /L of water treated for electrodes made of non-recycled aluminum, and 6,63.10-4 DZD (4,4.10-6 $) /L of treated water for electrodes in cans.

GRAPHICAL ABSTRACT



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Introduction

The textile industry is among the few large industries that consume considerable amounts of water at different stages of textile processing, which leads to a wide variety of wastewater characteristics [1].

Textile industry effluents are one of the significant sources of environmental contamination and public well-being, mainly in many urban regions. These effluents are severely polluted with the complex organic and inorganic chemicals used during various textile processing steps. The new constituents from each step are discharged as wastewater which possesses intense color due to residual dyes, high organic and inorganic matters, turbidity, pH, and toxic chemicals. The presence of a minimal amount of residual dye in water is evident and consequently affects the receiving environment not only aesthetically but also disturbs the aquatic life by hindering the light penetration and oxygen transfer. The carcinogenic and mutagenic ability of various azo dyes and their precursors produces detrimental effects on the environment [2].

Many treatment methods include biodegradation, adsorption, precipitation, membrane filtration, chemical degradation, photodegradation, and chemical coagulation to remove dyes from colored effluents. However, these processes are quite expensive and involve several operational problems. Therefore, there has been an increasing interest in the use of electrochemical methods. Electrochemical methods have advantages due to no requirement of chemicals before and after treatment, producing less sludge and requiring small areas and low investment cost. Moreover, the high electrolyte (e.g., NaCl, Na_2CO_3, Na_2SO_4, and inorganic salts) concentration used in the textile dying process offers an inherent advantage for treating used dye bath effluent with electrocoagulation (EC) [3].

Electrocoagulation is a process that generates metallic ions by electrochemical dissolution of a soluble sacrificial anode. The application of the electrocoagulation process to the treatment of wastewater does not require any addition of chemical salts. This process promotes high removal efficiency for many types of pollutants in a shorter treatment time with a comparatively meager operating cost. Electrocoagulation has been tested on many types of effluents. Existing studies show that the electrocoagulation process is very effective for the treatment of many types of water, such as the treatment of wastewater charged with heavy metals, the defloration of natural water, the treatment of water flowing from a tobacco factory, suspended solids, oil, and fat in restaurants, and surface water [4].

The main electrochemical reactions inside the cell are [5]:

At the anode: the place of oxidation, aluminum passes from the solid state to the ionic state according to reaction 1.

$$Al_{(s)} \rightarrow Al^{3+} + 3e \qquad (1)$$

At the cathode: the reactions that can take place to depend on the solution's pH to be treated. At neutral or basic pH, hydrogen is produced according to reaction 2, whereas in an acid medium, equation 3 best describes the evolution of hydrogen at the cathode.

$$2H_2O_{(l)} + 2e \rightarrow H_{2\,(g)} + 2OH^- \qquad (2)$$

$$2H^+_{(g)} + 2e \rightarrow H_{2\,(g)} \qquad (3)$$

In recent years, we have seen that the quality of the air and soil is also deteriorating due to certain factors, including pollution and the increase in the number of wastes. This is why many countries are looking for alternatives to overcome this problem. This is how the concept of sustainable development appears.

However, the aspect of sustainable development that we have chosen to study is the recycling, recovery, and reuse of metal waste (aluminum cans).

This study's objective is to apply an electrocoagulation process for the elimination of Azucryl red (AR) textile dye using recycled aluminum electrodes (cans), and also a modeling study by the experimental plans is made for the EC.

Materials and Methods

The experiments carried out in this work were set in static methods. Under the chosen operating conditions, two liters of colored solution is introduced into the glass reactor in which are immersed two soluble electrodes of recycled aluminum of approximately identical dimensions: length of 8.2 cm and a width of 3.4 cm with a thickness (t) t = 0.5 cm giving an active surface of 65,66 cm^2, a power supply continuous flow is ensured by a current generator, stirring and homogenization of the solution is ensured by a magnetic stirrer.

Azucryl red dye

Azucryl red (AR) is a basic textile dye dyed cotton. The physicochemical properties of AR are summarized respectively in the Table 1.

Results and Discussion

Optimization of operating conditions

Effect of pH

In wastewater treatment using electrocoagulation, pH plays a significant role in determining efficiency [7]. The pH effect on the treatment efficiency was examined by altering the initial pH from 5 to 10 and keeping other parameters constant. The results obtained are reported in Figure 1.

Table 1: Physicochemical characteristics of Azucryl red [6]

Usual name	Chemical formula	Molecular mass	water solubility	λ_{max} (nm)	Pka	color index I.C
Azucryl red	$C_{18}H_{21}BrN_6$	401.3	High	533	3.8	110825

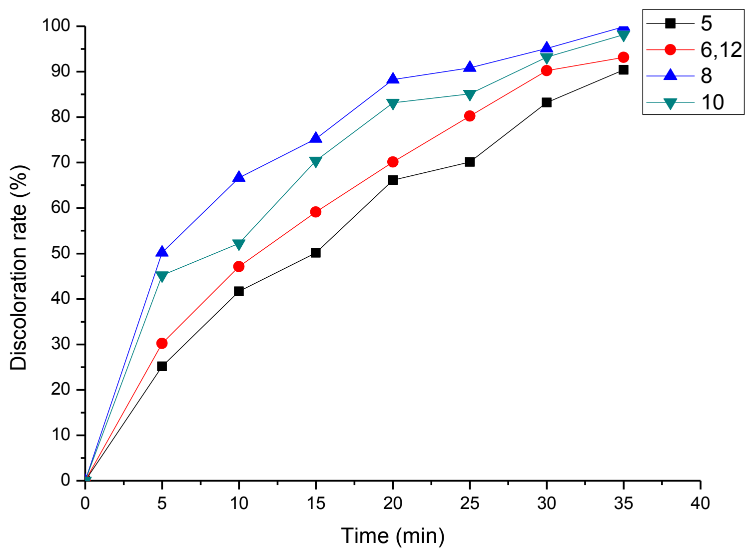

Figure 1: Evolution of the discoloration rate as a function of time for initial pH values (Int = 0.25 A, Dis = 1 cm, [NaCl] = 1 g/L, and $[dye]_0$ =10 mg/ L)

According to the results in Figure 2, it can be seen that the best values of pH favoring the elimination of "Azucryl Red" by the EC process are at slightly basic pH and that the maximum elimination (90,84 % at pH = 8) is obtained in the first minutes of treatment up to 25 min.

Basic media promote the appearance of hydroxide ions, which can react with the Al^{3+} ions released by the anode to transform into $Al(OH)_3$; this precipitate is the element that ensures the coalescence of destabilized colloids; it is the flocculant form [8].

To follow the initial pH evolution of the colored solution as a function of the treatment time by electrocoagulation, the following figures have been drawn:

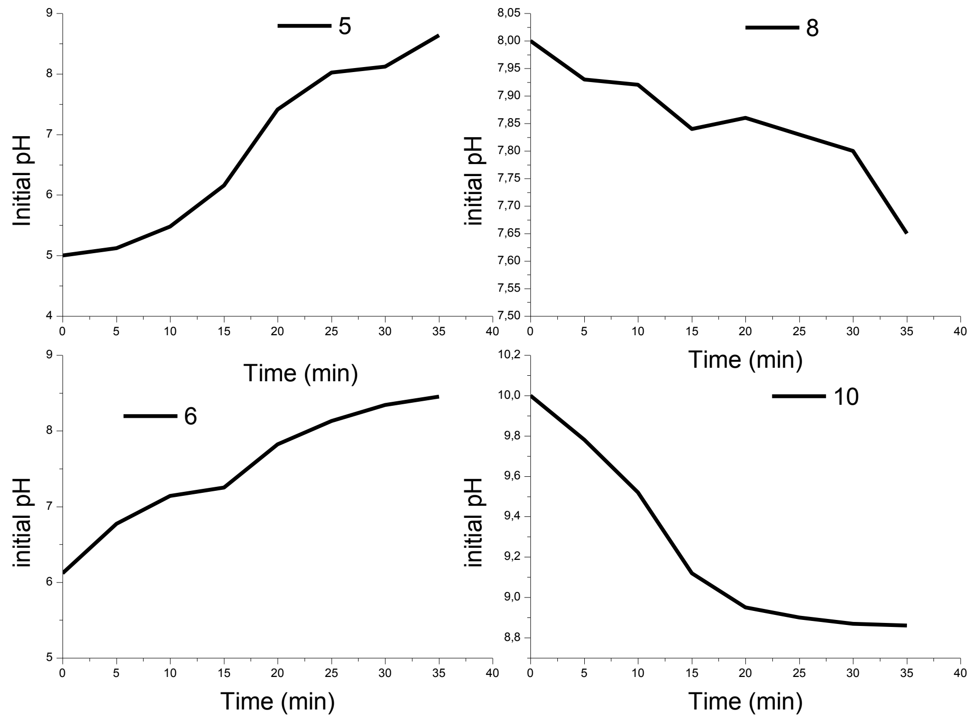

Figure 2: Evolution of the initial pH as a function of time ([NaCl] = 1 g/L, $[dye]_0$ = 10 mg/L, Dis = 1 cm, and Int = 0.25 A)

According to Figure 2, it can be noticed that the initial pH of the solution varies during the treatment by the EC process; the pH increases when it is in an acid medium, and it decreases in an alkaline solution.

For an initial pH = 5 and 6

As previously mentioned, the pH increases as a function of time, which is reflected by a lowering of the acidity of the medium. This is perhaps explained by a reduction of H+ ions at the level of the cathode with a clear observation of hydrogen evolution (reaction 3).

For basic pH

The observed decrease in pH over time is probably explained by the reaction of Al^{3+} ions with hydroxide ions according to the following reaction (4).

$$Al^{3+} + +3OH^{-} \rightarrow H_{2\,(g)} + Al(OH)_3 \qquad (4)$$

The process of $Al(OH)_3$ formation is therefore active for a pH range from 4 to 9.

This pH interval encompasses the initial pH optimum found in our case. However, pH strongly affects the size of hydrogen bubbles [9]. The typical size of the bubbles produced during electrocoagulation by aluminum electrodes varies between 20 and 70 μm [10].

Effect of current intensity

The current density is considered as an essential parameter in electrocoagulation [11-13], specifically for the kinetics of abatement of COD, turbidity, and discoloration.

In our case, the coagulant is produced by electrode dissolution, so it is essential to know the effect of the intensity of the current applied to the latter's terminals [12]. To establish the effect of the applied electric current on the removal of the dye by the EC process, we repeated the same tests with different current intensities (0.15A, 0.2A, 0.25A, and 0.35A).

Figure 3 shows the variation of the discoloration rate as a function of time and for different intensities of the applied current.

On reading these graphs (Figure 3), it appears that the application of ascending current intensity values improves the dye removal rate. Similarly, we find that the best intensity that we allow to reach the maximum elimination is of the order of 0.25 to 0.35A, and for reasons of energy saving, we have chosen the intensity of 0.25 A. the dye reduction rate corresponds to this intensity is 97.41%. To explain the role of current intensity in the elimination of pollutants in general, several researchers have shown that at high current densities, the anodic dissolution of aluminum increases, resulting in a higher rate of precipitates necessary for the elimination of pollutants [14-16]. Likewise, as the level of gas bubble production increases, their sizes decrease with the increase of the intensity of the current applied, which can be beneficial for an excellent performance of pollutant removal by hydrogen flotation [17].

Effect of inter-electrode distance

The inter-electrode distance is also an important parameter to determine since it defines the relative volume of electrolyte per unit area of the electrode. Several researchers have studied the impact of the inter-electrode distance on the efficiency of the elimination of pollutants by EC [18].

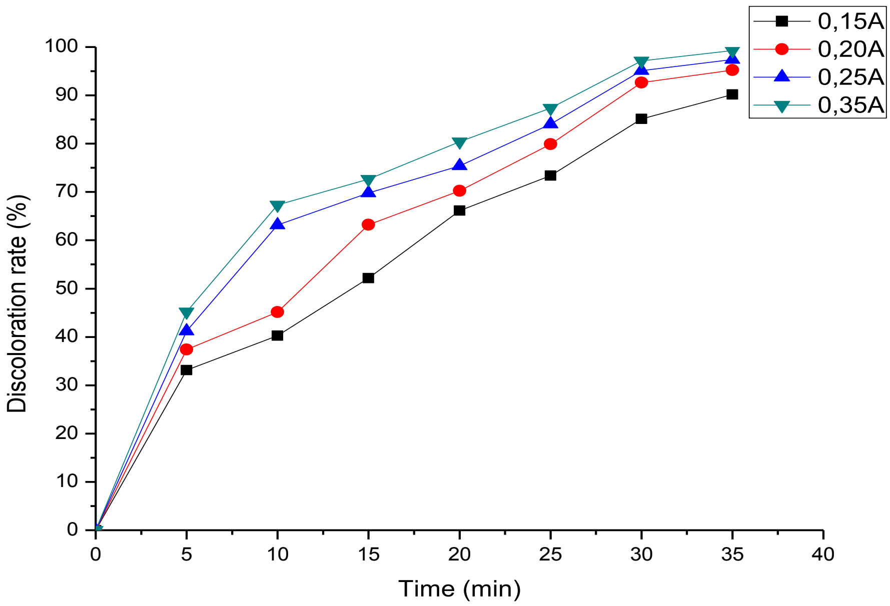

Figure 3: Variation of discoloration rate as a function of time for different current intensities (Dis=1cm, [NaCl]=1g/L, $[dye]_0$=10 mg/L, and pH=8)

This distance depends on the nature of the pollutants on the structure of the electrodes. In this study, the impact of (Dis) was studied at four different distances; 1, 2, 2.5, and 3 cm. A decrease in the efficiency of the treatment was observed when the space between the electrodes was increased [19, 20]. Based on Figure 4, it was noticed that the best efficiency was about 99.88% at d=1cm. Molecular interactions between ions and hydroxide polymers become weak when the distance exceeds 1 cm [21], which leads to lower treatment efficiency. This decrease in efficiency probably occurs because the electrostatic effects depend on the inter-electrode distance, so when this distance increases, the movement of the produced ions would be slower, and they will have less opportunity to aggregate and produce flocs of aluminum hydroxide, which will negatively affect the discoloration kinetics [22].

In addition, the release of hydrogen H_2 at the cathode at a short distance (Dis =1 cm) allows the flotation phenomenon to extract the flocs, which will improve the efficiency of the treatment [23].

Effect of salinity

Similar effects of improving the elimination of pollutants by increasing the conductivity by the addition of salt have been reported by different authors [24, 25].

We carried out a series of tests with different concentrations of NaCl, the purpose of which was to see its effect on the elimination of the dye (discoloration rate). The results are shown in Figure 5.

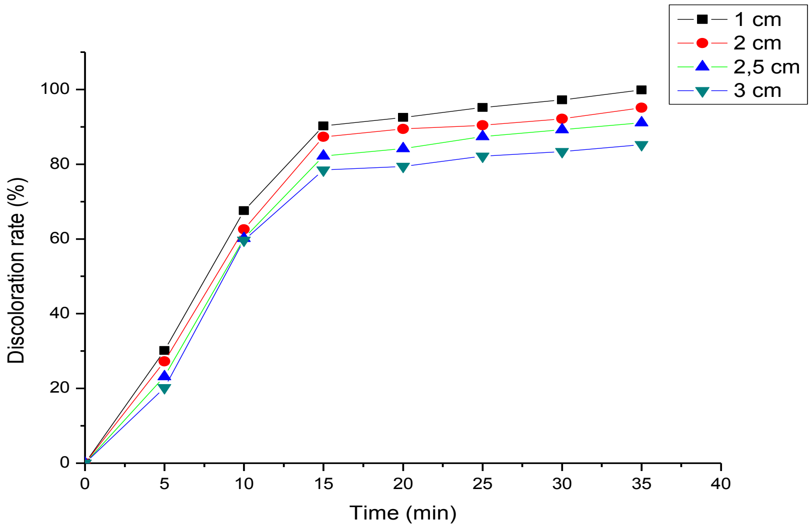

Figure 4: Effect of the inter-electrode distance on the discoloration rate as a function of time (Int= 0.25 A, [NaCl] = 1 g/L, pH =8, and $[dye]_0$ = 10 mg/ L)

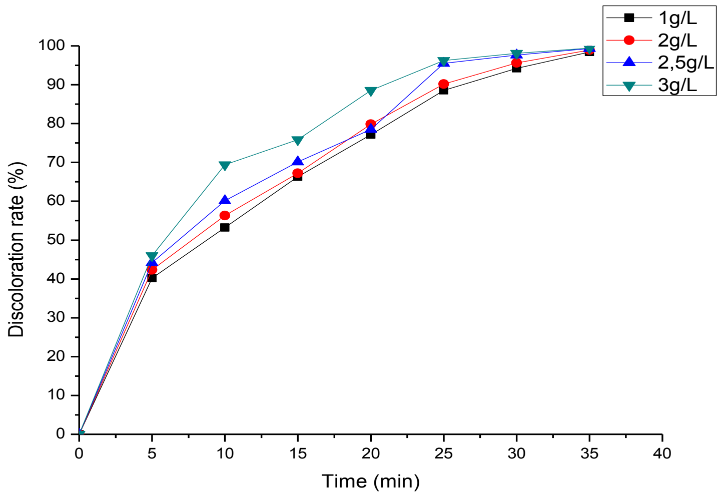

Figure 5: Evolution of the discoloration rate as a function of time for different NaCl concentrations (Int = 0.25 A, pH = 8, $[dye]_0$= 10 mg/L, and Dis =1 cm)

According to Figure 5, the shape of the curves is similar for the different NaCl contents, and after 35 minutes, a yield of 98.41 % is reached by operating with a salinity of 1 g/L. The highest yield (99.32 %) is achieved by operating with a salinity of 2.5 to 3 g/L after 35 minutes. Similar effects of improving the elimination of pollutants by increasing the conductivity by adding salt have been reported by different authors [26-30].

Influence of the initial dye concentration

Given the synthetic nature of our affluent, it was considered interesting to study the effect of the initial concentration of Azucryl red on the elimination of the latter by the electrocoagulation process. For this, we carried out tests at initial concentrations of 10 to 50 mg/L. The results obtained are displayed in Figure 6.

On reading these results, it is observed that the removal efficiency of Azucryl red decreases when its initial concentration increases. In addition, it is observed that the times required to reach dye removal percentages of 80 to 85% are higher for the high concentrations. This is due to the lack of metal hydroxide formed at the electrodes, which will coagulate the dye [31, 32].

Influence of the nature of the electrodes

It has been established that the nature of the electrode plays an essential role in the electrolytic process [33, 34]. In our study, we tested the effect of two types of electrodes: can Aluminum (recycled) and non-recycled aluminum. The results obtained are given in Figure 7.

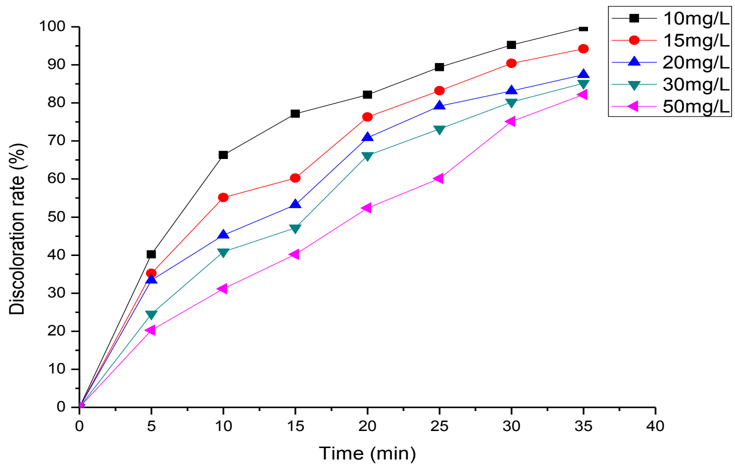

Figure 6: Elimination of the dye under the effect of its initial concentration (mg/l) as a function of time (Int = 0.25 A, Dis = 1 cm, [NaCl] = 1 g/L, and pH = 8)

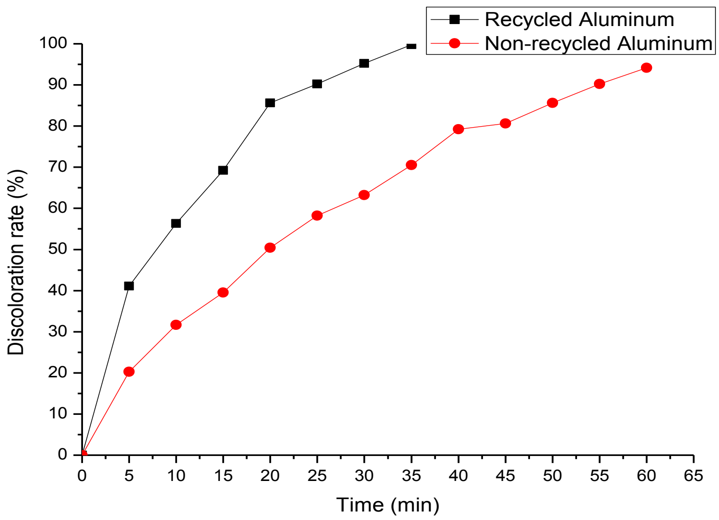

Figure 7: Evolution of the discoloration rate of two types of aluminum as a function of time (Int = 0.25 A, Dis =1 cm, [NaCl] = 1 g/L, and initial pH =8)

From this figure, it is clear that aluminum of the cans favors better the elimination of the dye by EC process compared to the non-recycled aluminum. Optimal yields are 99.76% at t=35 min for can electrodes and 94.16% at t=60 min for non-recycled aluminum.

Optimization technique by the design of experiment

Experimental plans make it possible to better organize the tests that accompany scientific research or industrial studies. They apply to many disciplines and to all industries from the moment one seeks the link that exists between a quantity of interest y and the variables xi [18].

Construction of the complete factorial plan

A complete factorial design is a design for which all the possible combinations at the limits of the field of study will have been carried out: this is the maximum number of trials for a factorial design of experiments [35]. The number of trials N is calculated using the following formula: $N = 2^k$ where k is the number of factors for k=3, so N=8 experiments.

For a classical factorial plan of the first degree, the construction of a complete plan with three factors is carried out by the following model [35]:

$$Y = a_0 + \sum_{i=1}^{3} a_i * x_i + \sum_{\substack{i=1 \\ j=2 \\ i \neq j}}^{3} a_{ij} * x_i * x_j \quad (5)$$

Where, Y: model response, a_i: model coefficients, and x_i: model variables.

Characteristics of the problem

Table 2 clearly shows the characteristics of this problem with a number of 8 experiments.

Choice of parameters

A literature review on electrocoagulation using aluminum electrodes shows that many factors have influenced the discoloration rate. The most varied parameters are grouped in Table 3.

Modeling the decolorization rate

Table 4 summarizes the different mathematical models regarding the discoloration rate for various times.

Table 2: Characteristics of the problem

The objective of the study	Study of main effects and interactions
Number of variables	3
Number of experiences	8
Number of coefficients	8
Number of responses	1

Table 3: The chosen parameters

Parameters	Unity	Domain
Initial pH (pH)	-	5-10
Distance (Dis)	Cm	1-3
Intensity (Int)	A	0.15-0.35
Answers studied (%)	$Y(\%) = \frac{\text{initial absorbance} - \text{final absorbance}}{\text{initial absorbance}} \times 100$	

Table 4: Modeling of discoloration rate

Time (min)	Model	R^2 (%)
10	$Y_{(at\ t=10min)}$ = 37,219 + 9,806 pH - 7,836 Dis + 1,059 Int - 6,699 pH*Dis + 2,456 pH*Int + 1,764 Dis*Int	99.98
15	$Y_{(at\ t=15min)}$ = 55,84 + 13,45 pH - 5,59 Dis - 5,72 Int - 11,79 pH*Dis + 5,01 pH*Int - 3,94 Dis*Int	93.11
20	$Y_{(at\ t=20min)}$ = 67,49 + 20,52 pH - 0,67 Dis - 4,45 Int - 4,78 pH*Dis + 2,87 pH*Int - 2,19 Dis*Int	97.38
25	$Y_{(at\ t=25min)}$ = 73,68 + 18,88 pH + 1,00 Dis - 3,76 Int - 3,08 pH*Dis + 2,75 pH*Int - 0,31 Dis*Int	98.82
35	$Y_{(at\ t=35min)}$ = 89,59 + 8,92 pH - 0,72 Dis - 0,15 Int + 0,18 pH*Dis - 0,27 pH*Int - 1,57 Dis*Int	95.94

Factorial diagrams

For each time, graphs of the effects and interactions for the different parameters are presented.

At t=10 min

Based on Figure 8, it is seen in the main effects graph that the initial pH and the intensity have a positive effect on the discoloration rate, but the distance has a negative effect. The interaction effects are very strong interactions between (pH-Intensity), (Distance Intensity), and a strong interaction between (pH-Distance).

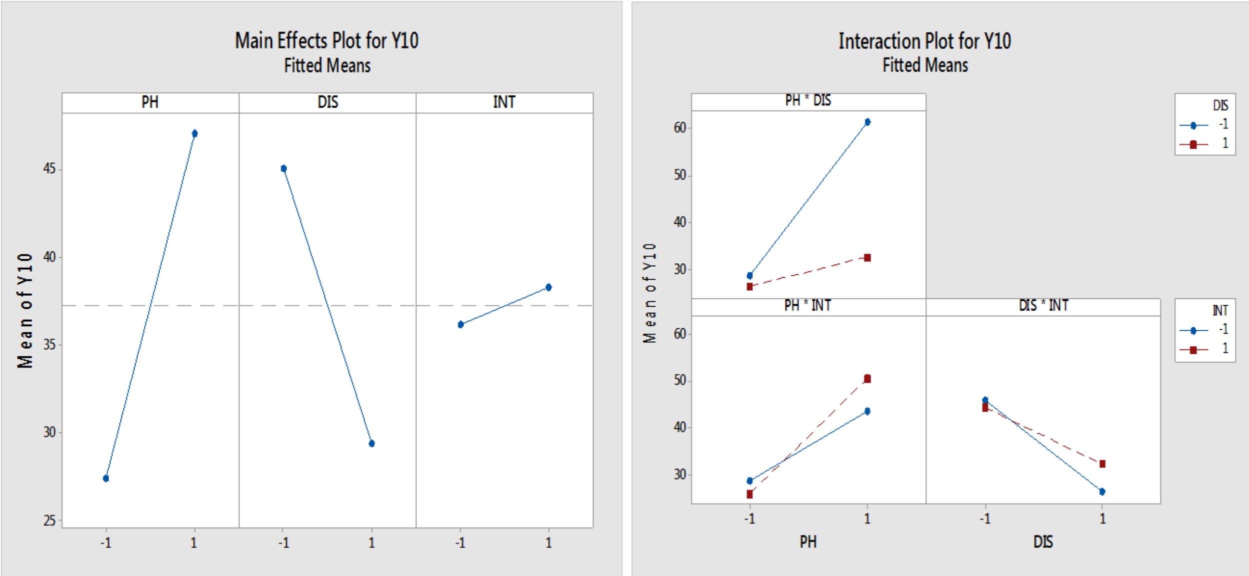

Figure 8: Graph of the main effects and interactions between the parameters for t=10 min concerning the modeling of the discoloration rate

At t=15 min

According to Figure 9, it can be seen in the graph of the main effects that the initial pH has a positive effect, the distance has a negative effect, and the intensity has no effect on the rate of discoloration. The effects interactions are very strong interactions between (pH-Intensity), (Distance Intensity), and (pH-Distance).

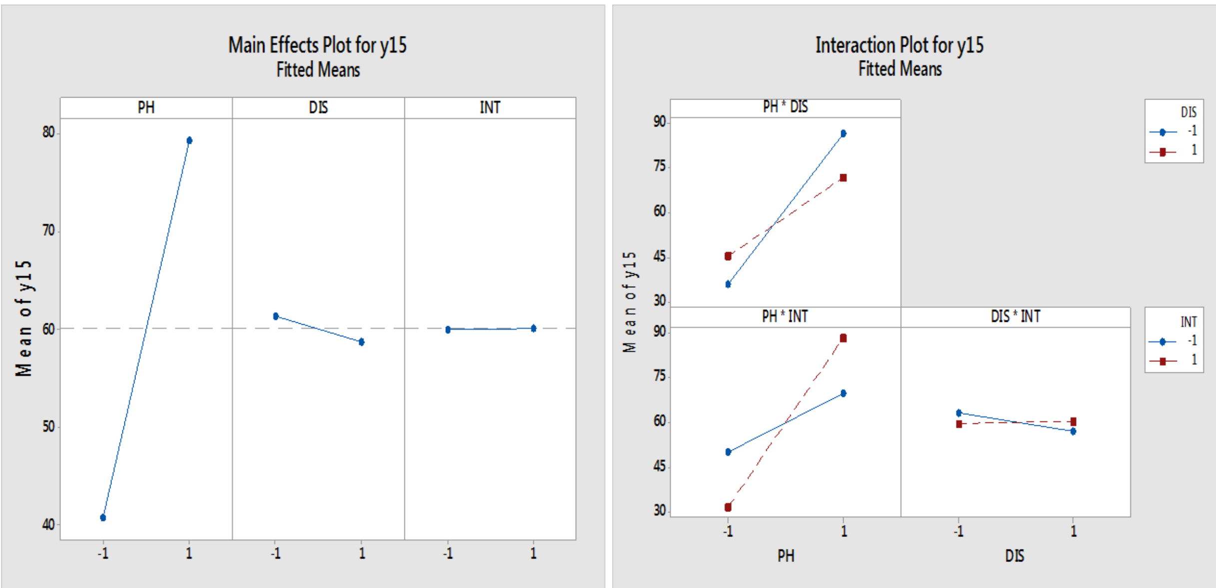

Figure 9: Graph of the main effects and interactions between the parameters for t=15 min concerning the modeling of the discoloration rate

At t=20 min

From Figure 10, it can be seen in the main effects graph that the initial pH has a positive effect, the distance has a zero effect, and the intensity has a negative effect on the discoloration rate, and for the effects interactions: Very strong interactions between (pH-Intensity), (pH-Distance) and strong interaction between (Distance Intensity).

At t=25 min

From Figure 11, it can be seen in the graph of the main effects that the initial pH has a positive effect, the distance has a positive effect, and the intensity has a negative effect on the rate of discoloration. The effects interactions are very strong interactions between (pH-Intensity) and (pH-Distance) and negligible interaction between (Distance Intensity).

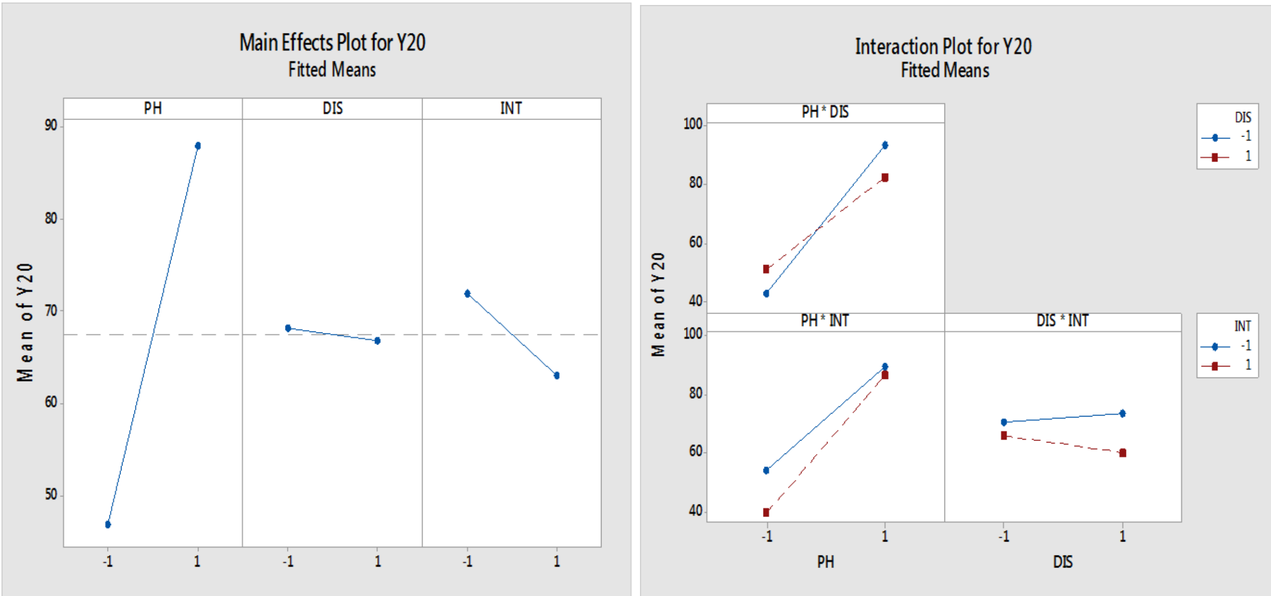

Figure 10: Graph of the main effects and interactions between the parameters for t=20 min concerning the modeling of the discoloration rate

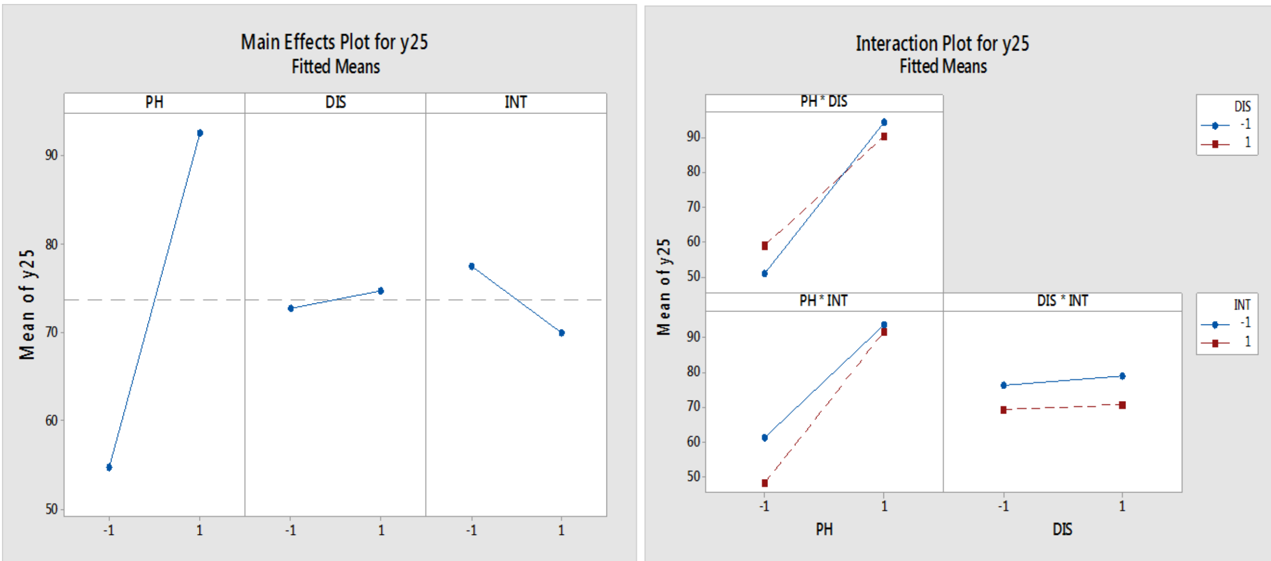

Figure 11: Graph of the main effects and interactions between the parameters for t=25 min concerning the modeling of the discoloration rate

At t=35 min

Based on Figure 12, it can be seen in the graph of the main effects that the initial pH has a positive effect, the distance has a negative effect, and the intensity has no effect on the rate of discoloration. The effects interactions are negligible interaction between (pH-Distance) and very strong interactions between (Distance Intensity) and (pH-Intensity).

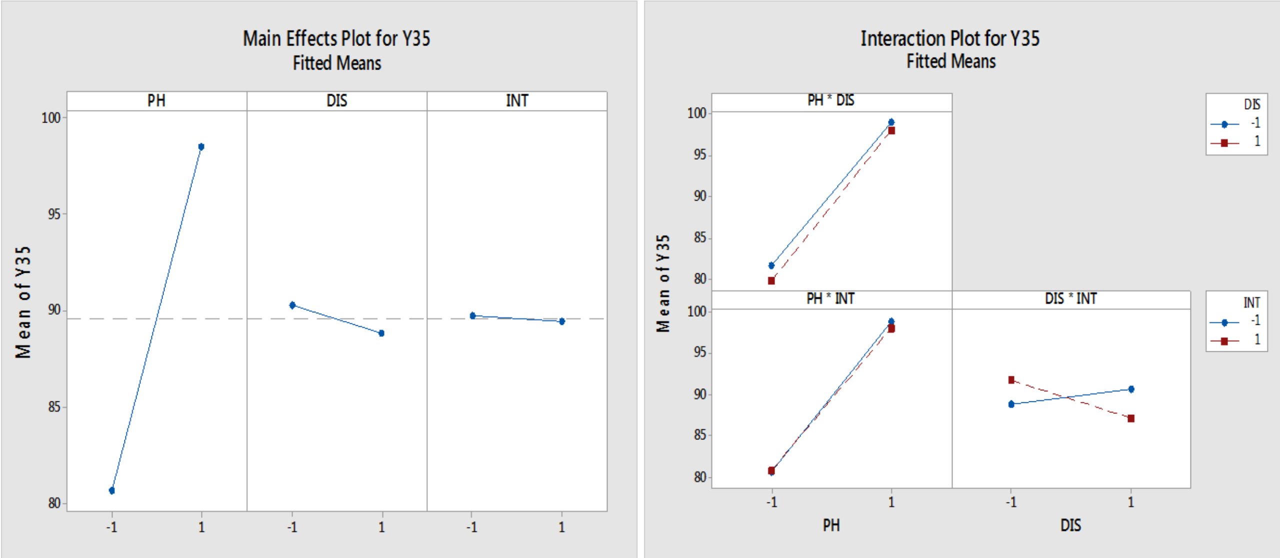

Figure 12: Graph of the main effects and interactions between the parameters for t=35 min concerning the modeling of the discoloration rate

Results calculated by EC mathematical models

The calculated results according to the obtained mathematical models in the case of EC are presented in this part, and a comparative study between the experimental and calculated results is also exposed.

Effect of pH on discoloration rate

On reading these graphs (Figure 13), the discoloration rate increases as a function of time, and a basic pH gives the best yields, as is found in the experiment.

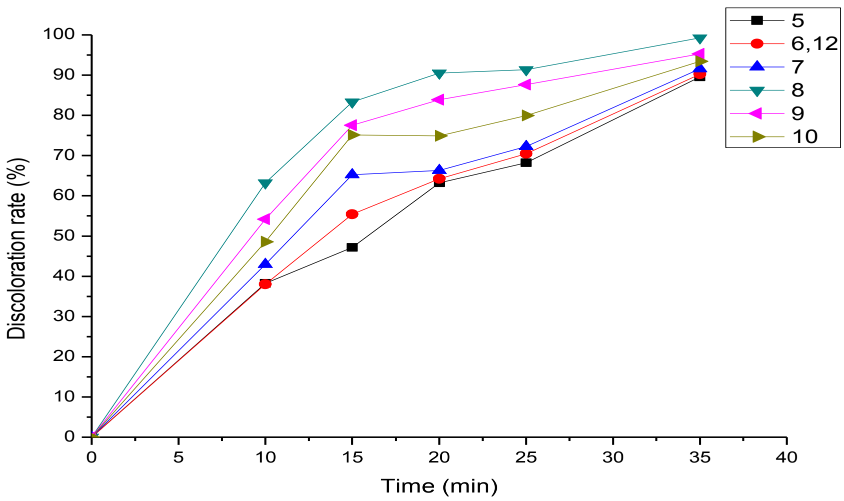

Figure 13: Evolution of the discoloration rate over time for different pH (Int = 0.25 A, Dis = 1 cm, [NaCl] = 1 g/L, and $[dye]_0$ = 10 mg/L)

Effect of the distance between electrodes on the discoloration rate

It is found in Figure 14 that the fading rate always increases with time, and the optimum distance is equal to 1cm.

Effect of current intensity on discoloration rate

On reading these graphs (Figure 15), it appears that the application of ascending current intensity values improves the dye removal rate, as is found in the experiment.

Comparison between the experimental results and the results calculated by the mathematical models of EC

To validate the models obtained, a comparative study between the experimental and calculated results was carried out for some parameters of the discoloration rates.

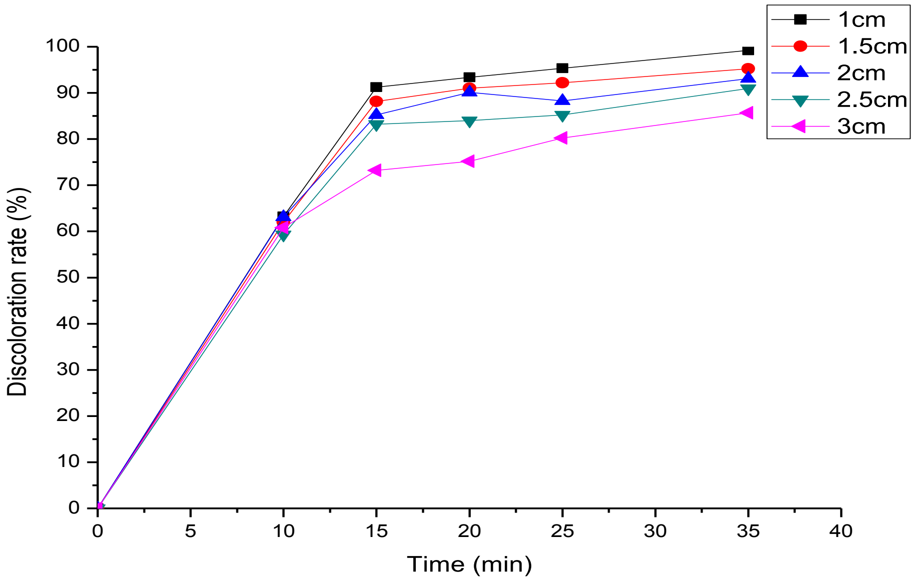

Figure 14. Evolution of the discoloration rate as a function of time for different inter-electrode distances (Int = 0.25 A, initial pH = 8, [NaCl] = 1 g/L, and $[dye]_0$ = 10 mg/L)

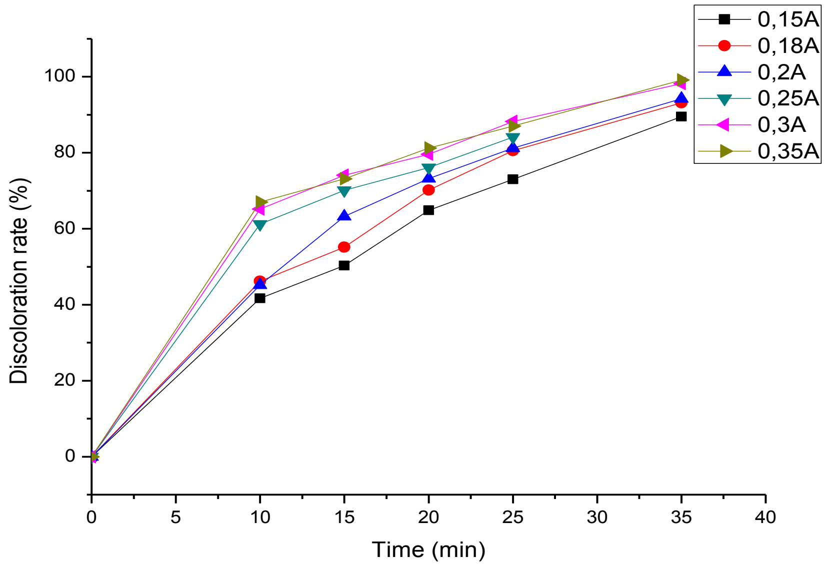

Figure 15: Evolution of the discoloration rate under the effect of the intensity of the current (A) as a function of time (dis=1 cm, [NaCl]=1 g/L, $[dye]_0$=10 mg/ L, and initial pH=8)

Effect of pH

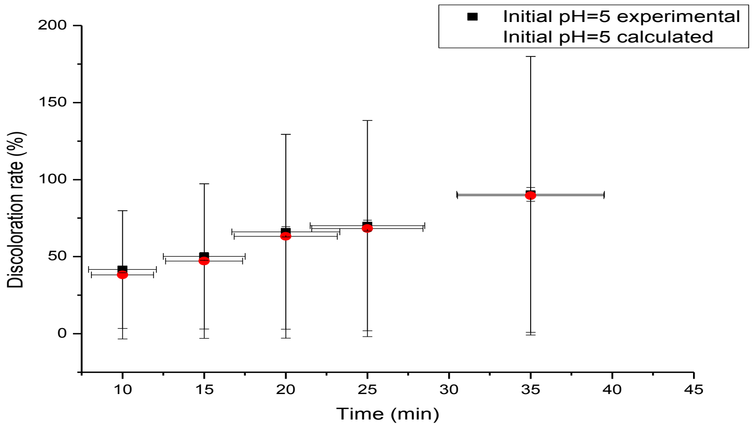

Figure 16: Comparison between experimental and calculated results for the pH of 5 of the discoloration rates (Dis=1 cm, Int=0.25A, [NaCl]=1g/L, and $[dye]_0$=10 mg/L)

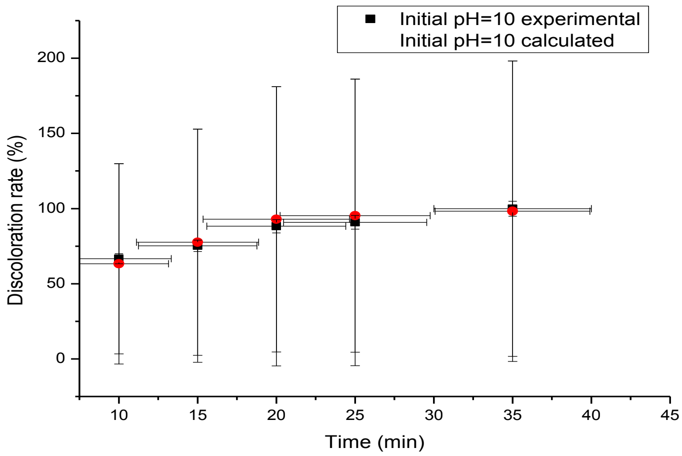

Figure 17: Comparison of experimental and calculated results for the pH of 10 of the discoloration rates (Dis =1 cm, Int = 0,25 A, [NaCl] = 1g/L, and $[dye]_0$ = 10 mg/L)

Effect of current intensity

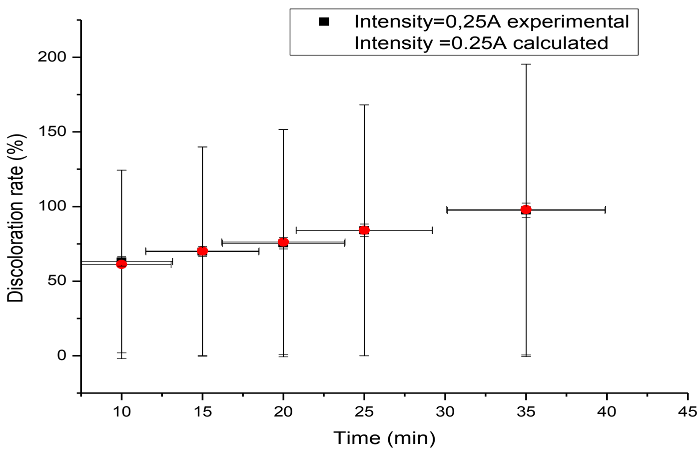

Figure 18: Comparison of experimental and calculated results for the 0.15A current intensity of the discoloration rate (initial pH=8, Dis=1cm, [NaCl]=1g/L, and $[dye]_0$=10 mg/L)

Effect of distance

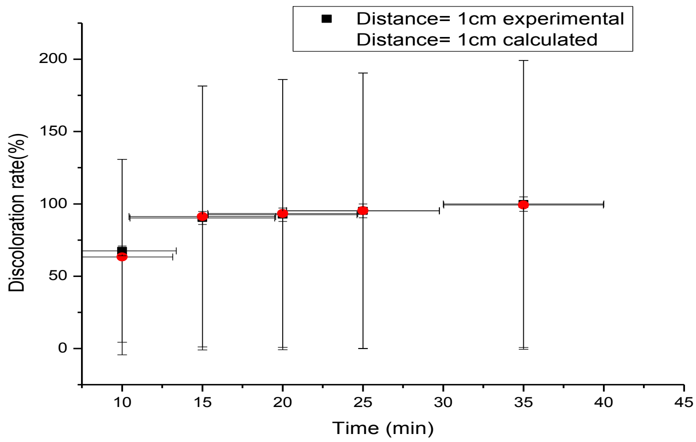

Figure 19: Comparison of experimental and calculated results for the distance of 1 cm from the discoloration rate (pH=8, Int=0.25A, [NaCl]=1g/L, and $[dye]_0$=10 mg/L)

All the curves presented in Figures 16, 17, 18 and 19 show good convergence between the results obtained experimentally and by calculation for the different parameters studied; the majority of the points are superimposed, which shows that our obtained models can be applied in CE processes.

Energy consumption is the treatment cost for EC

In this part, we tried to estimate the cost of the treatment by the electrocoagulation process; after 60 minutes of electrolysis, we calculated the electrical consumption and the cost of treatment for different current intensities applied. The Operational Cost C_0 is given by the following formula [36]:

$$C_0 = a\, C_{energy} + b\, C_{Al^{3+}electrode} \quad (6)$$

Where,

a and b are ratios concerning the price of energy in Algeria market (2022).

C_{energy}: Energy consumption;

$C_{(Al3+)\ electrode}$: Aluminum consumption Al^{3+};

They are of the order of a = 1.904 DA/kWh.

And b = 250 DZD/kg of recycled aluminum cans.

b = 1500 DZD/kg of non-recycled aluminum.

The value of the energy consumption according to the treated water is calculated according to the following equation [36]:

$$C\ energy = \frac{U.I.t}{V} \quad (7)$$

Where, U is the applied voltage (V), I is the current (A), t is the electrolysis time (h), and V is the volume (m^3) of water treated at the optimal electrolysis time.

The aluminum consumption value at the electrodes is calculated according to the following Faradays law [36]:

$$CAl^{3+}(electrode) = \frac{I.t.M}{Z.F.V} \quad (8)$$

Where, I is the intensity of the applied current (A), t is the electrolysis time (s), M is the molecular weight of Aluminum (26.98 g/mol), Z is the number of electrons transferred (Z =3), F is the Faradays constant (96487 C/mol), and V is the volume (m^3) of reactor solution. The results obtained are grouped together in Table 5.

According to the costs of treatment by electrocoagulation, we notice that the latter increases with the intensity of the current. On the other hand, we can consider that for intensity of 0.25A (optimal intensity), the treatment cost is $3,52.10^{-3}$ DZD ($2,4.10^{-5}$ \$) /L of treated water for non-recycled aluminum electrodes and $6,63.10^{-4}$ DZD ($4,4.10^{-6}$ USD)/L of treated water for electrodes in cans.

Table 5: Electrocoagulation cost study

			Non-recycled Aluminum 60 min		Recycled Aluminum (of cans) 35 min	
Experiments	I (A)	Voltage (V)	Energy consumed (kWh/m^3)	Total cost (DZD/L)	Energy consumed (kWh/L)	Total cost (DZD/L)
EXP 1	0.15	2.9	$2{,}18.10^{-4}$	$1{,}36.\ 10^{-3}$	$1{,}27.\ 10^{-4}$	$2{,}95.\ 10^{-4}$
EXP 2	0.20	3.1	$3{,}1.\ 10^{-4}$	$2{,}28.10^{-3}$	$1{,}81.\ 10^{-4}$	$4{,}40.\ 10^{-4}$
EXP 3	0.25	3.7	$4{,}63010^{-4}$	$3{,}52.\ 10^{-3}$	$2{,}70.\ 10^{-4}$	$6{,}63.\ 10^{-4}$
EXP 4	0.35	3.9	$6{,}83.\ 10^{-4}$	$6{,}47.10^{-3}$	$4{,}19.\ 10^{-4}$	$7{,}09.\ 10^{-4}$

Conclusion

The experimental results for electrocoagulation allow us to say that the application of this process gives very satisfactory dye removal yields (RT), a yield of 99.76 % for a treatment time of 35 min, an initial pH of 8, the intensity of 0,25 A, and distance 1cm is obtained for the electrodes of recycled cans; and a yield of 94,16 % is obtained for the non-recycled electrodes for a time of 60 min. Likewise, from an economic viewpoint, through the results we have obtained, we can say that coagulation is a very economical technique since the price of the treatment for the recycled electrodes is $6{,}63.10^{-4}$ DZD ($4{,}4.10^{-6}$ $)/L of treated water for the intensity of 0,25A. The models obtained by the experimental design represent the experimental results well. However, not all cans are recovered and recycled in Algeria, so it is important to encourage the recovery and total recycling of all cans consumed.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

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HOW TO CITE THIS ARTICLE

Kenza Elhadeuf, Nabil Bougdah, Fouzia Balaska, Mustapha Chikhi. Experimental Study and Modeling by the Complete Factorial Plan of the Elimination of Textile Dye by Electrocoagulation Using Aluminum from Recycled Cans. *Chem. Methodol.*, 2023, 7(3) 183-199

https://doi.org/10.22034/CHEMM.2023.369066.1624

URL: http://www.chemmethod.com/article_162543.html