Turbidity Removal from a Model Solution by Continuous Mode Electrocoagulation and Evaluation of Energy Consumption

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Abstracts: The purpose of the research has been the construction of a new electrocoagulation (EC) equipment and its technical evaluation in the treatment of a model solution with a high level of turbidity. The EC system contains six cells installed in series, coupled to a flocculator and a clarifier (sludge decanter), each cell unit is composed of a cylindrical aluminum (Al) anode and a solid stainless-steel rod as cathode in connection with a DC power supply, the aluminum anodes are replaced by iron (Fe) according to the proposed tests. The influence of two factors, such as the applied electric potential and the type of electrode used, on turbidity removal performance, total dissolved solids (TDS) and electrical energy consumption were examined. The tests were carried out using a two-factor factorial design, electrical potential at (0, 3, 6 and 9 V) and type of anode (aluminum and iron). The investigation of the operating parameters was carried out in continuous mode. The initial turbidity of the water to be treated was set at 84.5 NTU, a value generally found in surface water. The results showed that the best conditions for turbidity removal were at an electrical potential of nine volts reaching a removal of 82.29 % and an energy consumption for aluminum electrodes of 0.7142 kWh/m3. It is also observed that the value of total dissolved solids after treatment is still slightly high. In conclusion, electrocoagulation with Al/steel electrodes proved to be an appropriate technology for water treatment due to its turbidity removal efficiency and low electrical energy consumption.

Keywords: Electrocoagulation; Factorial Design; Wastewater Treatment; Turbidity Removal; Energy Consumption.

1. INTRODUCTION

Water scarcity and pollution have become increasing global problems due to population growth, industrialization and overuse of water resources [1]. In recent years, electrocoagulation (EC) technologies have gained recognition as an effective, environmentally friendly and feasible water and wastewater treatment process for removing a wide variety of pollutants [2]. Electrocoagulation (EC) is an electrochemical technology that has its origins in traditional chemical coagulation. Compared to conventional chemical coagulation, EC treatment improves the removal of turbidity, TSS and COD [3]. EC is a process by which chemical coagulants are produced by connecting sacrificial anodes to an electric current [4]. Soluble contaminants and colloids are adsorbed on the coagulant and can then be removed by sedimentation [5]. As they reported, EC is an emerging technology for wastewater treatment because it combines the benefits of coagulation, flocculation and electrochemistry[6]. The EC process has proven to be effective in the treatment of a wide range of contaminants, such as color, turbidity, suspended solids, COD, heavy metals and other macromolecular organic compounds [7]. In its simplest form, the EC consists of an electrolytic cell with two metal electrodes, a sacrificial anode and a cathode, both immersed in an electrolyte solution to be treated and externally connected to a DC power supply, as shown in Figure 1. Metal dissolution occurs exclusively at the anode, even though the electrodes are made of the same material [8].

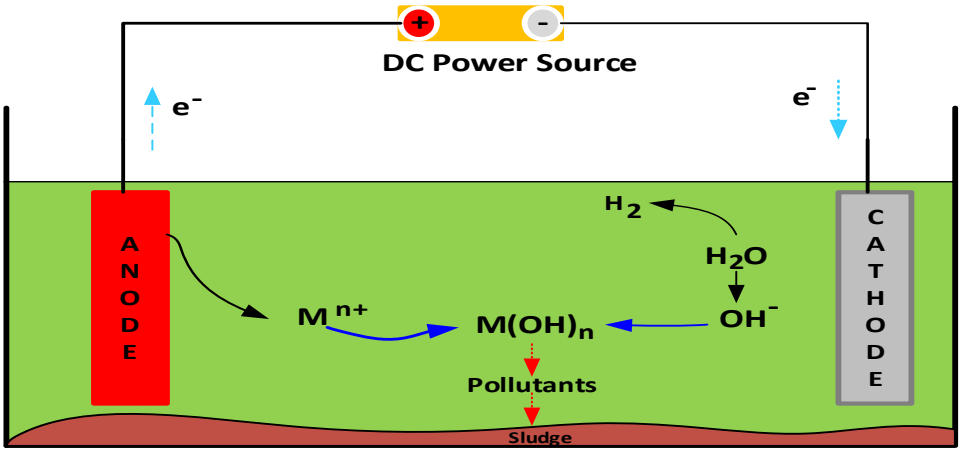


Figure 1. Simple electrocoagulation cell, where M is metal, n is the oxidation state of the metal.

The reactions that take place at the electrodes can be summarized as follows:

Anode reactions

Two anodic reactions can take place in this process. Equation (1) refers to the oxidation of the metal, by which metal cations are generated, where z is the number of electrons transferred during anodic dissolution, per mole of metal [9] . Where M is usually mainly aluminum (Al), iron (Fe).

$$M_{(s)} \rightarrow M_{(aq)}{}^{n+} + ze^- \qquad (1)$$

Previous studies have revealed the use of electrodes (anode) in electrocoagulation cells such as, Magnesium [10] ,

Copper [11], Zinc [12][13] and Titanium [14][15]. In the case of aluminum electrodes subjected to direct current, the main reaction generated is as follows.

$$Al_{(s)} \rightarrow Al_{(aq)}{}^{3+} + 3e^- \qquad (2)$$

In parallel, in case of a high anodic potential, water undergoes oxidation (Equation (3)), with the production of hydronium and oxygen [16]. Several authors indicated that the evolution of oxygen in the anode could take place with an alkaline pH and a sufficiently high anodic potential [17].

$$2H_2O_{(l)} \rightarrow 4H_{(aq)}{}^{+} + O_{2(g)} + 4e^- \qquad (3)$$

In case the presence of Cl^- [18] . The chloride ion is oxidized, resulting in the formation of chlorine gas and hypochlorous acid which are strong oxidizers (equation 4 and 5).

$$2Cl_{(aq)}{}^{-} \rightarrow Cl_{2(g)} + 2e^- \qquad (4)$$

$$Cl_{2(g)} + H_2O_{(l)} \rightarrow HClO_{(aq)} + HCl_{(aq)} \qquad (5)$$

1 These secondary reactions, equation (3,4) cause a minor production of coagulant [19].

2 **cathode reactions**

3 At the cathode, water is reduced (equation (6)), resulting in the formation of hydrogen gas and hydroxyl ions. This reaction is independent of the metal used as cathode.

$$2H_2O_{(l)} + 2e^- \rightarrow 2OH_{(aq)}{}^- + H_{2(g)} \quad (6)$$

Metal cations (M^{n+}) may be reduced at the cathode surface electrochemically [21]

$$M_{(aq)}{}^{n+} + ne^- \rightarrow nM_{(s)} \quad (7)$$

The presence of noble metal ions such as Cu^{2+}in solution gives rise to the following reaction simultaneously with H_2 evolution [22].

$$Cu^{2+} + 2e^- \rightarrow Cu_{(s)} \quad (8)$$

The anode material determines the type of coagulant (usually aluminum or iron), while the cathode can be made of stainless steel, titanium etc. However, when the polarity is changed to prevent anodic passivation, the two electrodes must be of the same material [23]. Metal ions (equation 1) with hydroxyl ions (equation 6) produce coagulating substances, which can be metal hydroxides (equation 9) or polyhydroxides, responsible for flocculation [24].. The hydroxide generated is used as a coagulant and has the ability to form flocs with a large surface area, which is advantageous for the rapid adsorption of contaminants in solution [25].

$$M_{(aq)}{}^{n+} + nOH_{(aq)}{}^- \rightarrow M(OH)_{n(s)} \quad (9)$$

Metal complexes such as $M(OH)^{(n-1)+}, M(OH)_2{}^{(n-2)+}$ and $M_6(OH)_{15}{}^{(6n-15)+}$ contributing to the neutralization of negatively charged organic substances and suspended solids [26]. Most EC studies focus on the effect of different operating factors, such as electrode material, electrode material, electrode size, and electrode size [27]. the inter-electrode distance [28] [29] , the current density [30][31] , the electrolysis time[32][33] , and the initial pH of the leachate [34] in pollutant removal efficiency. The EC method, on the other hand, is affected by high energy consumption and also by electrode passivation [9]. Thus, the batch electrocoagulation method showed inferior results in terms of contaminant removal, performance with high energy consumption and operating costs [25]. García et al [9], in analyzing the different CE reactors that have been used, they point out that 91% of the studies used vertical plate batch reactors [35]. , Hashim et al (2017) state that the design of CE reactors has not changed significantly over the last few decades. In general, rectangular reactors with flat electrodes were, and still are, the predominant design [36]. To date, most EC studies have been carried out in laboratory-scale batch reactors for wastewater treatment (Shahedi et al., 2020), installation and operation are very simple.

The main objective of this research was to design a new EC reactor, which would operate in continuous mode and replace the flat electrodes with a metallic steel tube and a solid bar of aluminum and iron. A simulated wastewater effluent was chosen and the effect of parameters such as applied electrical potential and anode material (Al or Fe) on the removal of turbidity, total dissolved solids, solution pH and specific energy consumption by the electrocoagulation cell was evaluated under constant values of treatment time (2 hours), distance between electrodes (0.55 cm), feed flow (23.88 L/h) and retention time per electrocoagulation cell (0.287 min).

2. MATERIEL AND METHODS

2.1. MATERIALS

All chemicals used were of laboratory grade**.** Chemical reagents such as 37% hydrochloric acid (HCl), 98% sulfuric acid (H_2SO_4) and solid sodium hydroxide (NaOH) were purchased from Cimatec. Distilled water was used throughout the test. For the preparation of the model solution, 400 grams of commercial natural fertilizer for gardening were mixed in 200 liters of tap water, mixed for 15 minutes and then allowed to stand for 24 hours, finally working with the homogeneous solution with an average turbidity of 84.4 NTU. The natural fertilizer was purchased from PROMART Homecenter.

2.2. Analytical Methods

The pH and total dissolved solids (TDS) were measured using the Cal Check HI9813-6 portable multiparameter, Hanna brand, and for turbidity, the TN2035 turbidity meter was used. Both devices were calibrated by the company Metrology and Engineering Lino S. A. C. before use.

2.3. Experiment design

In order to achieve adequate testing and systematic studies, the design of experiments was used. Two factors, electrical potential and electrode material, have been evaluated for their effect on turbidity removal, pH change, water STD and energy consumption by the electrocoagulation cell. The electrocoagulation cell was evaluated at four levels (0, 3, 6 and 9 V) of electrical potential, the treatment was carried out with anodes of (aluminum and iron). Different electrodes have been mentioned in the literature, but iron and aluminum electrodes are the most efficient and successful for effluent decontamination at low prices. [38]. Table 1 shows the factors and levels studied. The design consists of eight trials with three replicates and the average is reported. An analysis of variance (ANOVA) was then performed to evaluate statistical significance using Desing-Expert 11 and Minitab 17 software.

Table 1 . Factors and levels of experimental design

Factors	Unit	Variable notation	Levels			
Electrical potential	V	X_1	0	3	6	9
Electrode type (ánode)	……	X_2	Aluminum		Iron	

2.4. Experimental apparatus and procedures

The electrochemical process includes six electrocoagulation cells as shown in Figure 2. Six aluminum anodes have been used in the EC system, and six stainless steel tubes act as cathodes. Each electrocoagulation unit contains two electrodes, a cylindrical aluminum rod (anode) and a stainless steel tube (cathode), the aluminum electrodes were replaced by iron according to the development of the experiments. Table 2 shows the characteristics of the electrodes used. The anode electrode comprises a cylindrical rod of (26 cm length and 2 cm outer diameter), while the cathode electrode comprises an outer tube of (26 cm length, 3.1 cm inner diameter and 3.5 cm outer diameter). Electricity was supplied to the electrodes through a UNI - UTP - 3305 brand direct current power supply, rated between 0 - 33 V and 0 to 5 A with a monopolar parallel mode (MP-P) electrical arrangement. The electrodes were placed on a metal structure with a height of 94 cm and a base of 43*43 cm2 to fix them. Before each test, the electrodes were polished on the outside using sandpaper to remove deposits and rinsed with distilled water. The separation between anode and cathode has been set at 5.5 mm to minimize energy losses [39]. In this study, the synthetic water used as a model solution is transported by a pump from the tank (50 L) to the EC reactor with a constant flow rate of 23.8 L/h. During all tests the hydraulic retention time per cell remained constant at 0.287 minutes. The experimental temperature was kept constant (28-30°C) during all tests. The treatment reactor is composed of two stages, the first consists of the electrocoagulation system followed by the purification stage where

the floc-formed and destabilized particles from the cells are separated by the flocculator and settler. The vertical flocculator was constructed of acrylic material with a capacity of 6.11 L and a retention time of 15,352 minutes; for the lamellar settler, acrylic material with a capacity of 4.62 L and a retention time of 11,608 minutes was used. The vertical flocculator and lamellar sedimenter equipment were designed and constructed according to the specifications established by [40]. The usability of the purification processes after electrocoagulation is very important since the outgoing flocs have fragile characteristics, are porous and can be restructured at pH 6.5 [41][42].

Table 2. Electrode characteristics

Specification	Unit	Electrodes	
		Cathode (steel)	Anode (Al and Fe)
Length	cm	26	26
Outside diameter	cm	3.5	2
Inside diameter	cm	3.1	…
Thickness	mm	2	…..
area	cm^2	253.20	163.35
Volume	cm^3	196.233	81.679
Volume of a cell	cm^3	114.554	

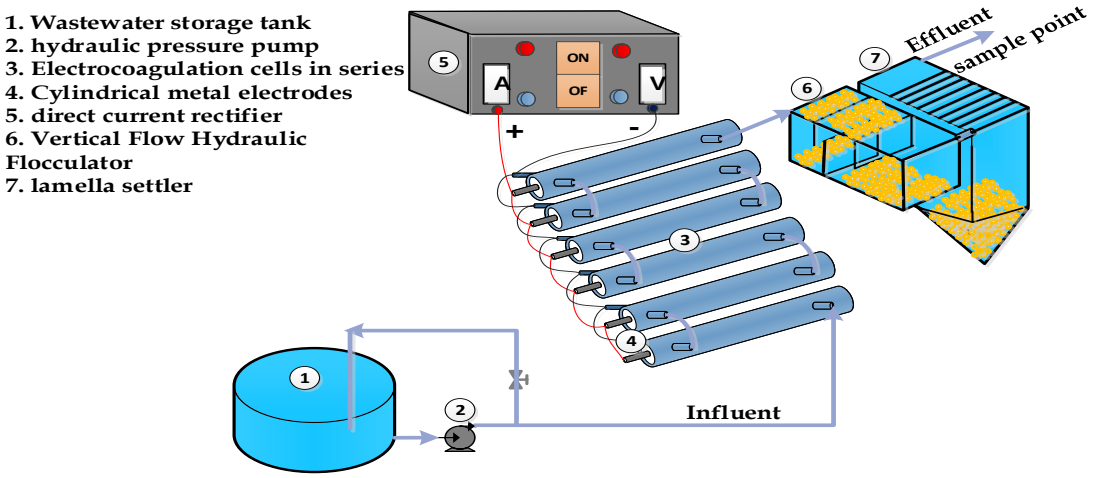


Figure 2. Experimental equipment

2.5. Calculations

The levels of reduction of turbidity concentrations achieved by the electrocoagulation equipment were determined by calculating the percentage of removal (R %) using Eq.(10) as follows

$$R(\%) = \frac{(C_0 - C_t)}{(C_0)} x100 \quad (10)$$

where C_0 and C_t are the concentrations of contaminants, turbidity (NTU) before and after the EC reactor treatments, respectively.

Anode consumption

The combination of electric current intensity and treatment time, which determines the amount of metal ion mass produced from the anode solution, can be calculated theoretically by Faraday's law using Eq.(11)

$$m = \frac{MIt}{zF} \quad (11)$$

Where m is the mass generated from the metal (g), M is the atomic mass of the electrode material (g/mol), F is Faraday's constant (1F = 96,486C), z is the number of electrons transferred per metal atom, which are three (Z_{Fe} = 2; and Z_{Al} = 3). In electrocoagulation treatments, the electric current intensity may vary with treatment time, the dissociated mass of the anode was calculated using [43]. Eq. (12) as follows

$$m = \frac{M \int_0^t I\, dt}{zF} \quad (12)$$

The consumption of electrical energy is an economic parameter of great importance in the electrocoagulation process. In this study, the specific electrical energy consumed (SEEC) is defined as the amount of electrical energy per cubic meter, was calculated by [44] [43] equation (13).

$$SEEC\ \left(\frac{kWh}{m^3}\right) = \frac{U \int_0^t I dt}{V} \quad (13)$$

where SEEC refers to specific electricity consumption kW-h/m^3), U refers to the voltage, I refers to the electric current (A), t refers to the time (hours) and V refers to the volume of the solution (m^3). In this case, the integration was solved by a Simpson 1/3 numerical method as follows:

$$\int_{0=x_0}^{t=x_n} f(x)dx = I(t) \approx \frac{h}{3}\left[f(x_0) + 4\sum_{i=1,3,5}^{n} f(x_i) + 2\sum_{i=2,4,6}^{n-2} f(x_j) + f(x_n)\right] \quad (14)$$

Time interval [0, t] is defined between 0 and experiment time (t), it can be divided into n equally spaced sub-intervals, of length (h) $h = \frac{t-0}{n}$

The retention time (τ) was evaluated from the constant flow rate of 100 mL/min and volume of each reactor unit (20 mL). It was calculated using equation (15).

$$\tau = \frac{V}{Q} \quad (15)$$

Where τ is the retention time (min), V is the reactor volume (L) and Q is the wastewater flow rate (L/min).

3. RESULTS AND DISCUSSIONS

Table 3 shows the results of the percent removal of turbidity, total dissolved solids, solution pH and specific energy consumption for each test. Tests for each experiment were performed in triplicate and the average is reported. The observed values of turbidity removal percentage and energy consumption reached up to 81.29 % and 0.944 kWh/m3 respectively.

Tabla 3. Results of the studied variables.

Run	Voltage (V)	Electrode type	Turbiedad (NTU) (%)		pH		STD (ppm)		Consumo de energía en la celda (KWh/m^3)
			Media	Error estándar	Media	Error estándar	Media	Error estándar	Ecuación (12)

1	9	Al	81,29	1,28	8,2476	0,0903	666,714	5,924	0,7142
2	6	Al	64,84	0,82	8,15	0,0452	659,285	3,785	0,3371
3	3	Al	20,33	0,6017	8,03	0,028	671,571	0,9691	0,137
4	0	Al	0,265	0,09	7,84	2,5876	675,666	0,885	0
5	9	Fe	39,68	1,11	8,52	0,022	650,857	5,723	0,944
6	6	Fe	25,49	0,75	8,35	0,019	673,238	2,360	0,3911
7	3	Fe	8,71	0,53	8,009	0,0347	676,095	1,314	0,139
8	0	Fe	0,33	0,11	7,89	0,002	675,761	0,876	0

3.1. Effect of Voltages Applied on Removal of Turbidity

One of the most important factors influencing the electrochemical coagulation process to reduce the contaminant load is the voltage applied to the electrocoagulation cell [45] [46]. Figure 3A shows the relationship between electrical potential and turbidity removal efficiency for aluminum and iron electrodes. Increasing the electrical potential increases the turbidity removal efficiency. The figure also indicates, when aluminum anode is used, the removal efficiency increases. Efficiency increases from 21% to 39% for iron anode and from 63 to 85% for aluminum when the electrical potential is increased from 6 to 9 volts. Figure 3 b shows the relationship between treatment time and turbidity removal efficiency. Increasing the electrolysis time increases turbidity removal. The effect of treatment time on turbidity removal is shown in Figure 3. It is observed that turbidity decreases rapidly in the first 60 min of treatment, and then decreases slowly in the following minutes, this behavior is observed for iron and pupil for 6 and 9 volts. The reason for the increase in turbidity removal is attributed to the increase in current density, since, as current density increases, the concentration of aluminum and iron increases linearly (Jiménez, Sáez, Martínez, Cañizares, & Rodrigo, 2012). Studies have reported the same effects of increased turbidity reduction as voltage levels increase, using iron electrode as the anode[47][48]. Another study where the effect on turbidity with increasing voltage, at all voltage levels, using aluminum as the anode showed a faster and higher turbidity removal than using iron as the anode [49]. In studies using aluminum, for three voltage levels, an increasing effect on turbidity reduction was observed as voltages were increased (1.5V, 2V and 2.5 V) [50]. In the research carried out, they compared iron and aluminum electrodes in the reduction of turbidity, obtaining greater turbidity removal using aluminum electrodes as opposed to iron [51]. In studies conducted, it was shown that increasing the voltage levels influenced the increase in turbidity reduction, this effect was seen for both electrodes (Al and Fe), it was also observed that aluminum has greater efficiency in the reduction of turbidity reaching 75% for a voltage of 10 volts, while for iron it reached 62%[52].

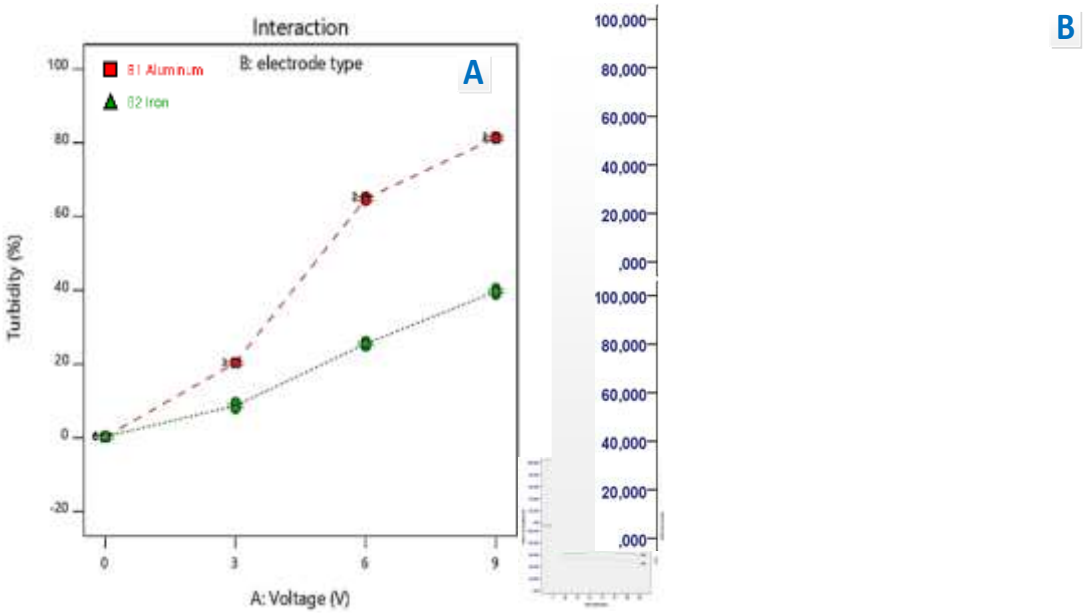


Figure 3. Variability of turbidity reduction (A) Percentage of turbidity reduction as a function of voltage levels for each electrode (B) turbidity reduction for each electrode as a function of treatment time.

3.2. Effect of the electric potential with solution pH

The influence of pH on the electrocoagulation process has been investigated by several authors [53][54] . Figure 4 shows the evolution of the pH of the mixture as a function of the applied electric potential, as can be seen it has not remained constant throughout the process, it has increased with the passage of time (reaction 6), which confirms some previous studies. The final pH value was higher than the initial value and was clearly dependent on the applied electric potential. The pH of water treated with aluminum electrodes was raised to 7.8, 8.1 and 8.3 and with iron electrodes to 8.1, 8.28 and 8.5 at an electrical potential of 3, 6 and 9 V, respectively. However, the pH did not vary significantly for both electrodes as a function of time as shown in Figure 4. The increase in pH is also due to the release of OH- at the cathode, which contributes to the neutralization of the final pH of the solution [55]. Previous studies detailed the same effect that the final pH is higher than the initial pH using iron electrode [56]. For a continuous process, using iron and aluminum as anodes, the same effect was observed, that the final pH is higher than the initial pH [57]. Likewise, in the report prepared by [47], The use of iron electrodes resulted in a higher final pH increase, and he also mentions that the electrocoagulation process acts as a buffer by consuming and producing (OH)- ions, results that are in agreement with our study. Recent studies have reported the same effects of increasing initial pH as treatment time elapses for a continuous process using cylindrical aluminum electrodes [58]. Another study reported the same effects of initial pH change over time for the integrated continuous EC-sedimenter process with aluminum electrodes[5]. For a 30-minute batch process of treatment on domestic wastewater, the initial pH of 6.86 rose to 7.8 for Fe as an anode and 7.9 for aluminum [59].

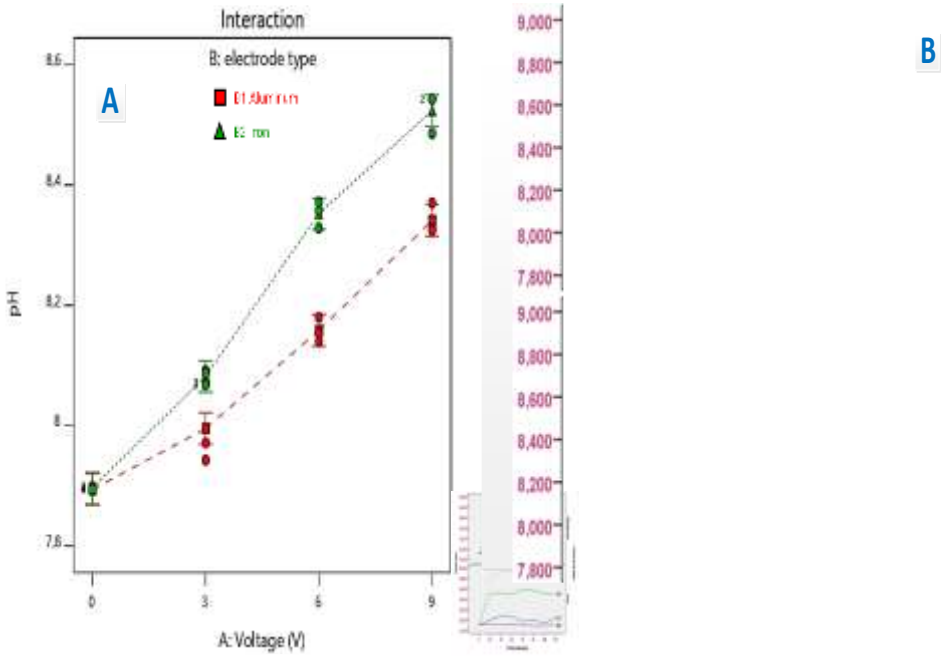


Figure 4. Variability of pH in the sample (A) pH reduction in the sample as a function of voltage for each electrode. (B) Average pH reduction as a function of time for each electrode.

3.3. Effect of applied electric potential on the removal of total dissolved solids.

The STD as an important parameter in the efficiency of the electrocoagulation process, begins to suffer a variability from the beginning of the electrocoagulation cell operation. Figure 5 A shows that the increase of the electric potential applied to the EC cell favors the decrease of the STD in the solution, this variation is more significant when an electric potential of nine volts is applied to both electrodes, likewise, it is observed that the use of anodes (aluminum and iron) does not make such a significant difference in the removal of STD. According to Figure 5B, we observe a decrease in the STD concentration in the first 45 minutes, then it decreases slowly during the remaining 75 minutes of operation, this trend is more pronounced at an electrical potential of nine volts. Resultados similares de han reportado por [60].

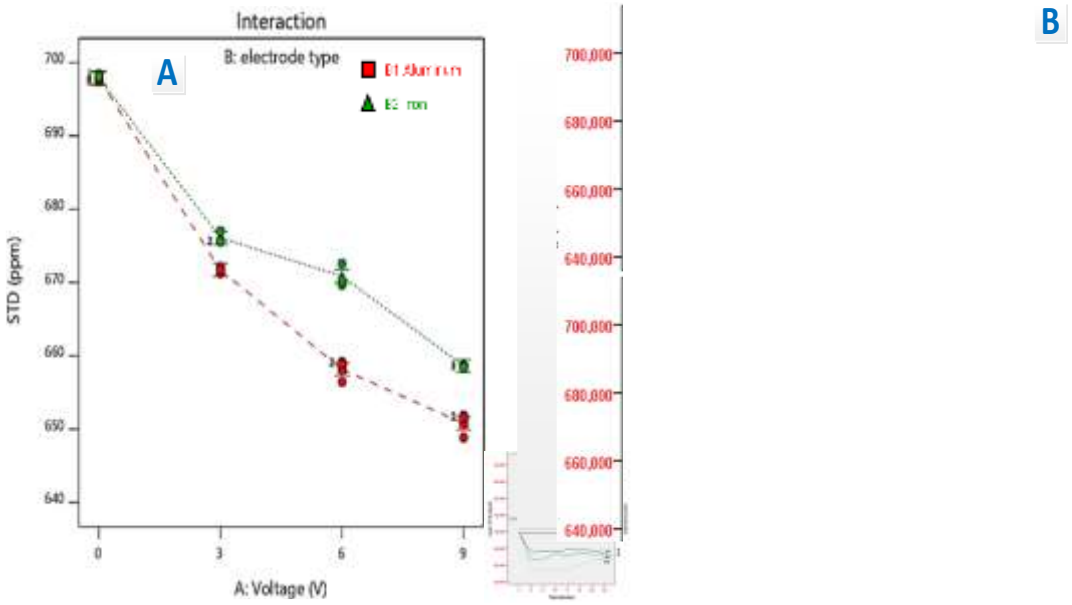


Figure 5. Variability of STD in the sample (A) STD reduction in the sample as a function of voltage for each electrode. (B) Average STD reduction as a function of time for each electrode.

3.4. Electric current analysis

Figure 6 shows the current intensity in relation to the treatment time using an electrical potential of (3, 6, 9) volts. It is observed that the current intensity decreases as the treatment time elapses for both electrodes (Al and Fe). In the first 45 minutes, this change is very significant particularly for voltages of 6 and 9 volts, while for 3 volts there is a slight decrease in amperage. The reason for these changes is due to the higher the current density applied, the higher the polarization and passivation (Sillanpää & Shestakova, 2017). It was also shown that increasing the current density has a direct influence on the passivation of the Fe electrode, this happens because it increases the total overpotential (η) at the electrode, which according to the Butler-Volmer equation, increasing the current density triggers the generation of O2 [61]. Furthermore, according to Figure 6, it can be observed that the STD decreases with time affecting the electrical conductivity of the electrolytic medium, increasing the electrical resistance, resulting in a decrease of the electrical current.

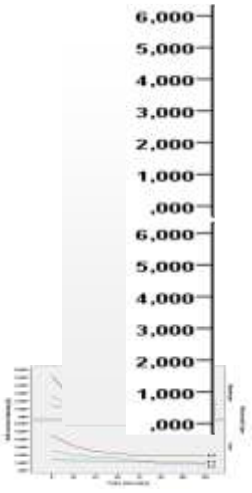


Figure 6. Variability of current intensity over electric potential

3.4. Electrode Consumption

The production of metal ions in electrocoagulation follows Faraday's law. This means that, in the EC, the higher the electric current used and the longer the operating time, the higher the production of metal ions in the electrochemical process, the mass released from the anode (Al and Fe) was calculated from equation (12). Likewise, the amount of anode dissolution depends on the intensity of electricity passing through the anode and the solution**[62].**

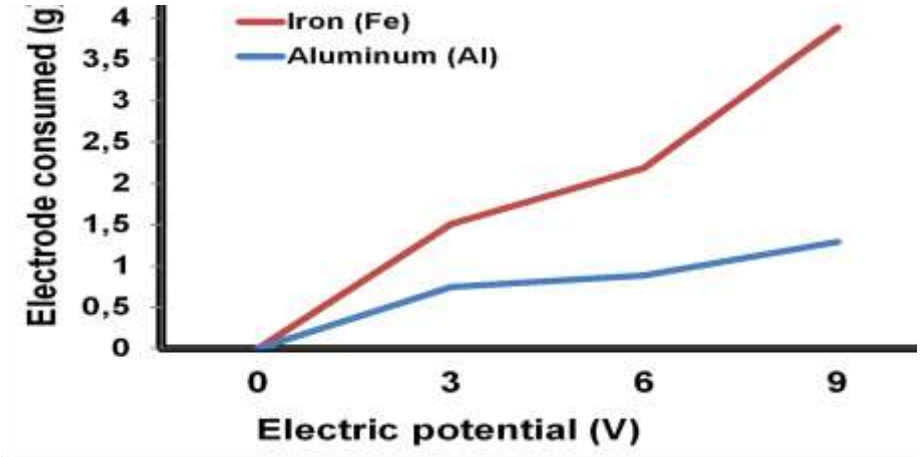
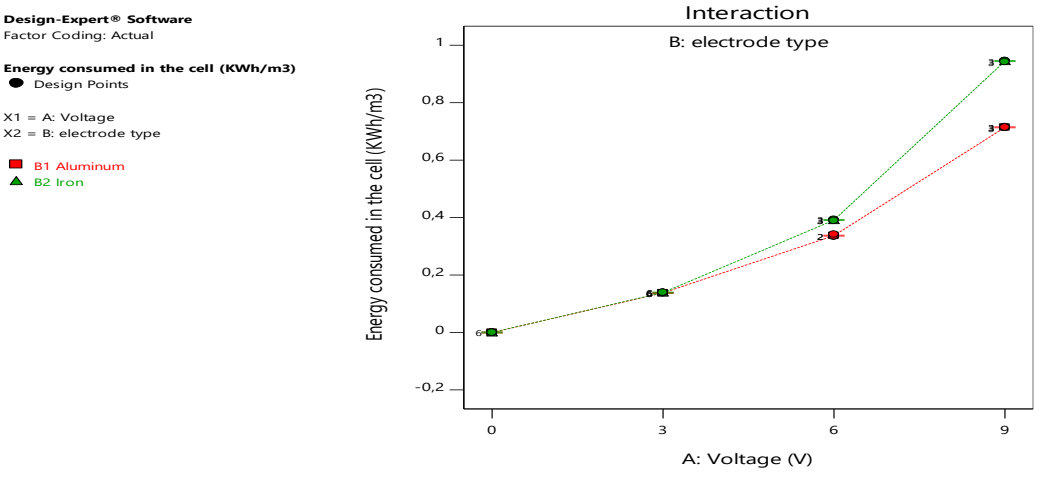


Figure 7. electrode mass consumption as a function of applied electrical potential

3.5. Consumption of electrical energy

Energy consumption as part of the operating cost of the electrocoagulation process plays an important role in the decision to choose this technology over other effluent remediation techniques **[63].** The electrical energy consumption (EEC) was calculated using Eq. (13) for the variables studied. As shown in Figure 8, the energy consumption is directly related to the applied electric potential and the material used as anode, also the higher energy consumption is generated using iron electrode than aluminum electrode for voltages higher than 3 volts. This difference in energy consumption observed for higher voltages is due to the fact that when iron is used, the current intensity during treatment does not decrease, unlike aluminum, since the higher the amperage fed to the cell, the higher the energy consumption [64]. For the study conducted by (Ehsani, Mehrdadi, Asadollahfardi, Bidhendi, & Azarian, 2020), the use of aluminum as electrode generates more power consumption than iron for different retention times for electrode distance conditions(1 cm) , current density (21mAcm^{-2}) [57]. In the study conducted by (Kambuyi, et al., 2020), to reduce turbidity by 72.05%, with a voltage of 5V, the energy consumption achieved was 0.210 KWh/m3, using aluminum electrodes for a continuous process [65].



3.6. ANOVA Analysis

In this study, analysis of variance (ANOVA) is used to correlate the interactions between factors and responses, as shown in Table 4, the (p) values of both models were less than 0.050, revealing that the terms of these models are significant. The p-value with 95% confidence interval reveals that both voltage and electrode type have a significant impact on the responses. The F-value of the model of 8182, which represents the turbidity reduction efficiency and 97216 refers to the power consumption, which means that there is only 0.01% chance that such a high F-value is obtained due to noise.

Table 4. ANOVA test results for turbidity removal efficiency, pH, STD and energy consumption.

Respuesta	Source	Sum of squares	df	Mean aquare	F-value	p-value	
% Turbidity	Model	18809,7178	7	2687,10255	8182,6251	3,2826E-27	significant
	A-Voltage	13687,4742	3	4562,49141	13893,4619	1,5691E-27	
	B-electrode type	3209,29834	1	3209,29834	9772,78861	1,0013E-23	
	AB	1912,94525	3	637,648417	1941,73384	1,0567E-20	
	Pure Error	5,25426012	16	0,32839126			
	Cor Total	18814,9721	23				
pH	Model	1,12609649	7	0,16087092	175,287514	6,5026E-14	significant
	A-Voltage	1,00802133	3	0,3360071	366,118678	5,9913E-15	
	B-electrode type	0,08168541	1	0,0816854	89,0057268	6,1377E-08	
	AB	0,03638974	3	0,01212991	13,2169470	0,00013445	
	Pure Error	0,01468407	16	0,00091775			
	Cor Total	1,14078056	23				
STD	Model	6526,54337	7	932,363338	887,821284	1,6695E-19	significant
	A-Voltage	6162,64201	3	2054,214	1956,07746	9,9647E-21	
	B-electrode type	236,164116	1	236,164116	224,881781	7,671E-11	
	AB	127,737245	3	42,5790816	40,5449393	1,0544E-07	
	Pure Error	16,8027211	16	1,05017007			
	Cor Total	6543,34609	23				
Energy consumed in the cell	Model	2,46128411	7	0,35161202	97216,1448	8,2907E-36	significant
	A-Voltage	2,37718999	3	0,79239666	219087,362	4,1163E-37	
	B-electrode type	0,03063148	1	0,03063148	8469,20455	3,1414E-23	
	AB	0,05346264	3	0,01782088	4927,24091	6,2336E-24	
	Pure Error	5,7869E-05	16	3,6168E-06			
	Cor Total	2,46134197	23				

CONCLUSIONS

The performance of the continuous mode electrocoagulation method in the removal of turbidity, STD and electrical energy consumption from a model solution was investigated in the present study. Two factors, such as the applied electrical potential and the type of electrode used, were examined for their influence on the removal performance and electrical energy consumption. The results revealed that the EC process is efficient in turbidity removal and low power consumption. The results showed that the best conditions for turbidity removal were at an electrical potential of nine volts and the use of an aluminum electrode, achieving an average turbidity removal of 81.29%. EC method can be used for treatment of water with high turbidity concentration, low energy consumption, TDS value after treatment remains slightly high. Therefore, more research is needed to study new EC reactor designs to achieve higher removal efficiency. Research efforts are also needed to clarify the operating conditions for scaling up the process to full scale. In conclusion, based on the results obtained, electrocoagulation integrated to

purification processes can be another alternative to traditional processes in surface water treatment.

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DOI: https://doi.org/10.15379/ijmst.v10i3.1704